

**FUNCTIONAL OUTCOME OF TIBIAL CONDYLE
FRACTURES TREATED BY MINIMALLY INVASIVE PLATE
OSTEOSYNTHESIS**



Dissertation submitted to

THE TAMILNADU DR.M.G.R. MEDICAL UNIVERSITY, CHENNAI,

In partial fulfilment of the requirements for the degree of

MASTER OF SURGERY IN ORTHOPAEDICS

Under the guidance of

Dr. V.SHYAM SUNDAR, M.S. (ORTHO) ,

Professor

DEPARTMENT OF ORTHOPAEDICS,

PSG INSTITUTE OF MEDICAL SCIENCES AND RESEARCH

COIMBATORE

2016

DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation entitled “**FUNCTIONAL OUTCOME OF TIBIAL CONDYLE FRACTURES TREATED BY MINIMALLY INVASIVE PLATE OSTEOSYNTHESIS**” is a bonafide and genuine research work carried by me under the guidance of **Dr.V.SHYAM SUNDAR, M.S Ortho**, Professor, Department of Orthopaedics, PSGIMS & R, Coimbatore.

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Acknowledgement

ACKNOWLEDGEMENT

At the outset. I thank the god for giving me the strength to perform all my duties.

It is indeed a great pleasure to recall the people who have helped me in the completion of dissertation, naming all the people who have helped me in achieving this goal would be impossible, yet I attempt to thank a selected few who have helped me in diverse ways.

I acknowledge and express my humble gratitude and sincere thanks to my beloved teacher and guide **Dr. Shyam Sundar M.S (Ortho)** Department of Orthopaedics, PSGIMS&R, Coimbatore for his valuable suggestion, guidance, great care and attention to details, that he has so willingly shown in the preparation of this dissertation.

I owe a great deal of respect and gratitude to my professor &HOD, **Dr.B.K.Dinakar rai M.S (Ortho)** for his whole hearted support for completion of this dissertation.

I also express my sincere thanks to Professor **Dr.Arvind Kumar M.S. (Ortho)**, Associate professors **Dr.N.Venkatesh kumar D.orth, DNB, Dr.Prasanna M.S (Ortho)**, Assistant professor **Dr.Vijayanth M.S. (Ortho)**, DNB, FNB and senior residents **Dr.Raghuveer chander M.S. (Ortho)**, DNB, and **Dr.Thirumurugan M.S. (Ortho)** department of

orthopaedics, PSGIMS&R, Coimbatore for their timely suggestions and all round encouragement.

My sincere thanks to the staff especially post graduate, colleagues and my friends for their whole hearted support.

Finally I thank my patients who formed the backbone of this study without whom this study would have not been possible.



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To
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Ref.: Proposal titled: *"Outcome of tibial condyle fractures treated by minimally invasive plate osteosynthesis: A retrospective and prospective observational study"*

Sub.: Ethics Committee Approval for the study

The Institutional Human Ethics Committee, PSG IMS & R, Coimbatore -4, has reviewed your proposal on 16th June, 2014 in its full board review meeting held at Research Conference Room, PSG IMS&R, between 9.30 am and 12.30 pm, and discussed your application to conduct the study entitled:

"Outcome of tibial condyle fractures treated by minimally invasive plate osteosynthesis: A retrospective and prospective observational study"

The following documents were received for review:

1. Duly filled application form
2. Proposal
3. Informed Consent forms
4. Data Collection Tool
5. Permission letter from the concerned Head of Department
6. CV
7. Budget

The members who attended the meeting at which your study proposal was discussed are as follows:

Sl. No.	Name of the Member of IHEC	Qualification	Area of Expertise	Gender	Affiliation to the Institution Yes/No	Present at the meeting Yes/No
1	Dr. S. Bhuvaneshwari (Member-Secretary, IHEC)	MD	Clinical Pharmacology	Female	Yes	Yes
2	Mrs. Geetha S Kannan	+ 2	Lay person	Female	No	Yes
3	Mr Gowpathy Velappan	BA., BL	Legal Advisor	Male	No	Yes
4	Mrs G Malarvizhi	M Sc	Nursing	Female	Yes	No
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9	Dr. P. Sathyan (Chairperson, IHEC)	DO, DNB	Clinician (Ophthalmology)	Male	No	Yes
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11	Dr. S. Shanthakumari	MD	Pathology, Ethicist	Female	Yes	Yes
12	Dr. Y.S. Sivan	Ph D	Social Scientist (Sociology)	Male	Yes	Yes
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14	Mrs. K. Uma Maheswari	M Sc, M Phil. B Ed	Botany	Female	No	No
15	Dr. D. Vijaya	M Sc, Ph D	Basic Medical Sciences (Biochemistry)	Female	Yes	Yes

After due consideration, the committee has decided to approve the above proposal.

The approval is valid for one year.

We request you to intimate the date of initiation of the study to IHEC, PSG IMS&R and also, after completion of the project, please submit completion report to IHEC.

We hereby confirm that neither you nor any of your study team members have participated in the voting/ decision making procedure of the committee. The members of the committee who have participated in the voting/ decision making procedure of the committee do not have any conflict of interest in the referenced study.

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Dr S Bhuvaneshwari

Member - Secretary

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Introduction

INTRODUCTION

The knee joint is complex and most commonly injured joint now because of increased motor vehicle accidents and sports related injuries. As it is a superficial joint, it is more exposed to external forces and gets easily injured.⁴⁴

Tibial plateau fractures with intra-articular extension are very difficult to manage. Age, skin conditions, compartment syndrome and osteoporosis further increase the obstacles in the healing process.

Complex biomechanics of its weight bearing position and complex ligamentous stability and articular congruency are the main reason why these fractures are of concern to surgeon.

The ideal treatment of high-energy tibial plateau fractures is controversial. Open reduction and stable internal fixation helps in maintaining the articular surface and restoration of the mechanical alignment which allows early mobilization of knee.⁴⁵⁻⁵² But, techniques of open reduction and internal fixation compromise the soft tissues and the rate of wound infection is relatively high.⁵³⁻⁵⁵

Various other methods of treatment like hybrid fixation and now plate fixation using minimally invasive technique have been suggested. Each method has its own advantage and disadvantages.

The development of locking implants has allowed the use of minimally invasive technique for unilateral plating³⁷⁻³⁹ with improvement in handling the soft tissue.⁴⁰⁻⁴³

There are lot of studies which assess the general outcome of these fractures but there are only few studies which assess the functional outcome of these fractures which is more important to the patient.

In our study we have evaluated the functional outcome of locking plate fixation of tibial condyle fractures using minimally invasive technique after a minimum period of 6 months after plate fixation by Rasmussen score and Knee society score.

Aims & Objectives

AIMS & OBJECTIVES

To evaluate the functional outcome of tibial condyle fractures treated by minimally invasive plate osteosynthesis technique by Rasmussen score and knee society score- six months followup.

Review of Literature

REVIEW OF LITERATURE

The fundamental principles and various modalities of treating tibial condyle fractures have improved over the past 50 years. In 1950s, 1960s, and 1970s, these fractures were managed conservatively by various non operative techniques and results were published using a variety of conservative techniques.

Apley⁸ corrected the deformity using longitudinal traction and maintaining it by nonoperative means. Early knee range of motion was started which was reported to have satisfactory results.

In a study reported by **Lansinger**⁵⁶ **et al.**, found that nonoperative treatment showed favourable outcome for fractures with <10 degrees of coronal plane instability in a 20 years follow up of patients.

Lambotte¹⁹ **in 1890** treated oblique tibial intra articular fractures with wires and screws.

Keetley¹⁹ **in 1899** described open reduction and wires for lateral condylar fractures.

Sir Robert Jones²⁰ **in 1920** noted in an article by W.H. Trethowan, the importance of realigning the intra articular fractures of tibia plateau by open reduction and internal fixation by bone pegs and long screws. He also

mentioned the need for elevating the depressed fragments from the tibial shaft.

Wilsons and Jacobs²¹ in 1952 used the articular surface of the patella for replacing the severely depressed comminuted fractures of lateral condyle.

A **Graham Apley⁸** in 1956 had done a study with 60 cases of lateral tibial condyle fractures with long term results. He managed these fractures conservatively with skeletal traction and physiotherapy without any internal fixation. One year follow up of 41 patients, excellent results were noted in 22, good results in 15, fair results in 7 patients and 1 patient had poor result. Finally he recommended early motion with traction as a satisfactory method in managing lateral tibial condyle fractures.

Rasmussen S. Poul and Gothenburg²² in 1973 followed a series of 260 fractures of one or both condyles. The main indication for surgical treatment was evidence of instability of extended knee. They treated 44% of patients with either traction, closed reduction or internal fixation using a wire loop or open reconstruction of joint surface using autogenous bone grafts. Follow up of 87% of these had an acceptable knee function.

SURGICAL ANATOMY OF KNEE :

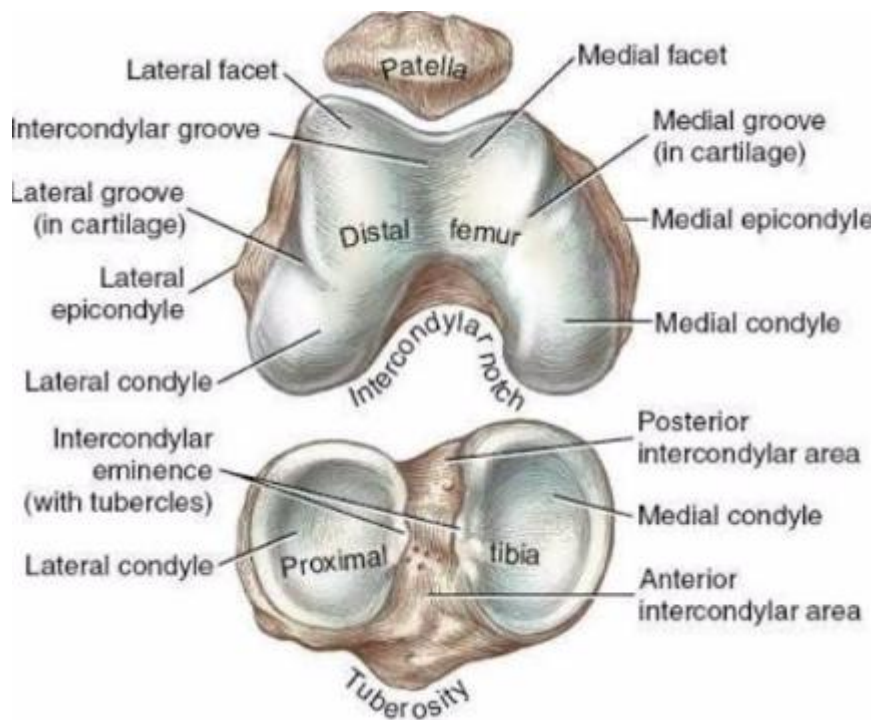
The knee is a complex joint in the body. It consists of three partially separate compartments.

- 1) Patellofemoral,
- 2) Medial tibiofemoral and
- 3) Lateral tibiofemoral.

The knee is composed of:

- 1) Bony structures
- 2) Extra-articular and
- 3) Intra-articular structures

BONY STRUCTURES



Femoral Condyles :

The femoral condyles are two rounded prominences, anteriorly the condyles are flattened which provides a large surface area for weight transmission. The condyles project in front of the femoral shaft. The articular surface is larger on the medial side when compared to lateral side.

Tibial Plateau:

The proximal tibia provides an adequate bearing surface for the body weight transmitted through the lower end of femur. It comprises of two prominent condyles 1) Medial and 2) Lateral condyles, which are separated by an intercondylar area. Anterior and posterior to the

intercondylar eminence serves as attachment for anterior and posterior cruciate ligaments and meniscus.

Medial condyle is larger as compared with the lateral condyle. The lateral condyle overhangs the shaft especially at its posterolateral part. The articular surfaces on the plateau are not equal, the lateral being wider than the medial. The medial plateau shows no significant concavity in the sagittal plane and the lateral plateau showing a slight concavity. In the coronal plane, the lateral plateau appears convex and the medial plateau appears concave.

Patella:

Patella, a triangular sesamoid bone situated between the quadriceps tendon and patellar tendon. The proximal wider portion is the base of the patella and the distal pole is narrow called the apex. The tendon of quadriceps femoris muscle attaches to the base of patella. The upper three quarters of patella articulates with the femur and is divided into medial and lateral facet. The distal part of the posterior surface of the patella has vascular canaliculi filled by fatty tissue called the Hoffa's fat pad.

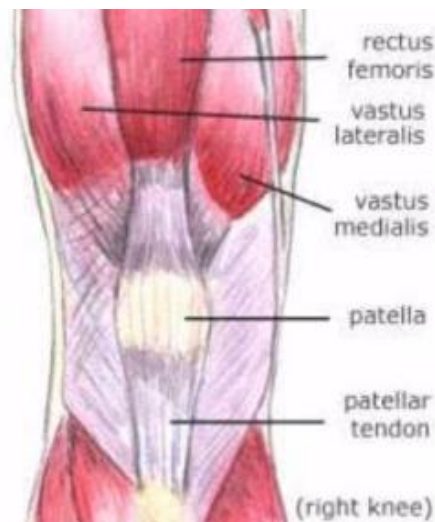
EXTRA ARTICULAR STRUCTURES

The extra articular structures comprises of musculotendinous units and ligamentous units.

MUSCULOTENDINOUS UNITS:

These are made up of :

ANTERIORLY



Quadriceps femoris

POSTERIORLY



Gastrocnemius

Popliteus

MEDIALY

Semimembranosus

Semitendinosus

Gracilis

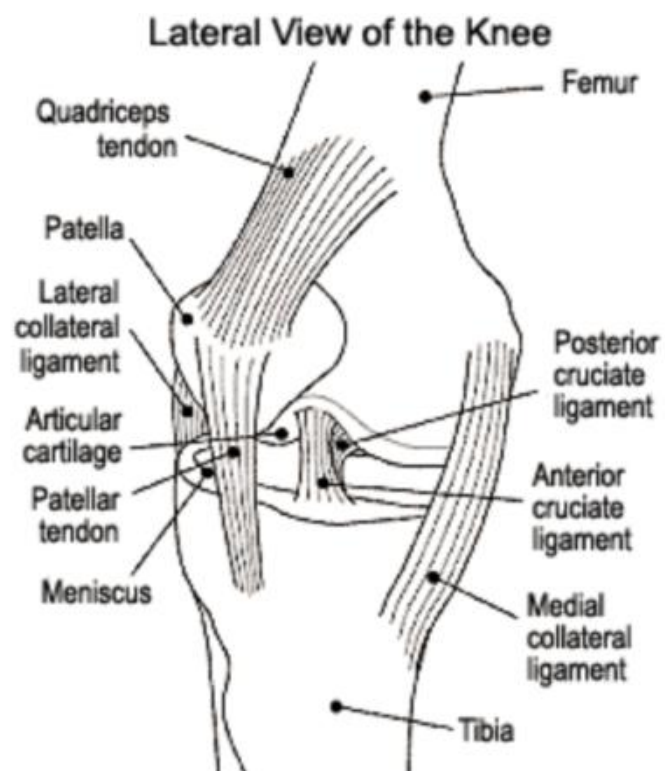
Sartorius

LATERALLY

Bicep femoris

Iliotibial band

LIGAMENTS



The capsular structures along with medial and lateral extensor expansions of the quadriceps are the principal stabilizing structures of the joint. It is reinforced by the medial and lateral collateral ligaments, hamstring muscles, popliteus muscle and iliotibial band.

The capsule is a sleeve of fibrous tissue extending from the patella anteriorly and extends to the medial, lateral and posterior aspect of the joint. The attachments to the bony structures are juxta articular. The menisci are firmly attached medially and less so laterally.

The medial capsule is more prominent than the lateral capsule.

The tibial collateral ligament lies superficial to the medial capsule and gets inserted 8 cms below the joint line. Proximally, tibial collateral ligament gets attached to the medial femoral condyle. The fibular collateral ligament gets attached proximally to the lateral femoral epicondyle and distally to the fibular head. It is important stabiliser of the knee against varus stress with knee in extension. Lateral collateral ligament has no role in stabilising the knee when it is in flexion.

INTRAARTICULAR STRUCTURES:

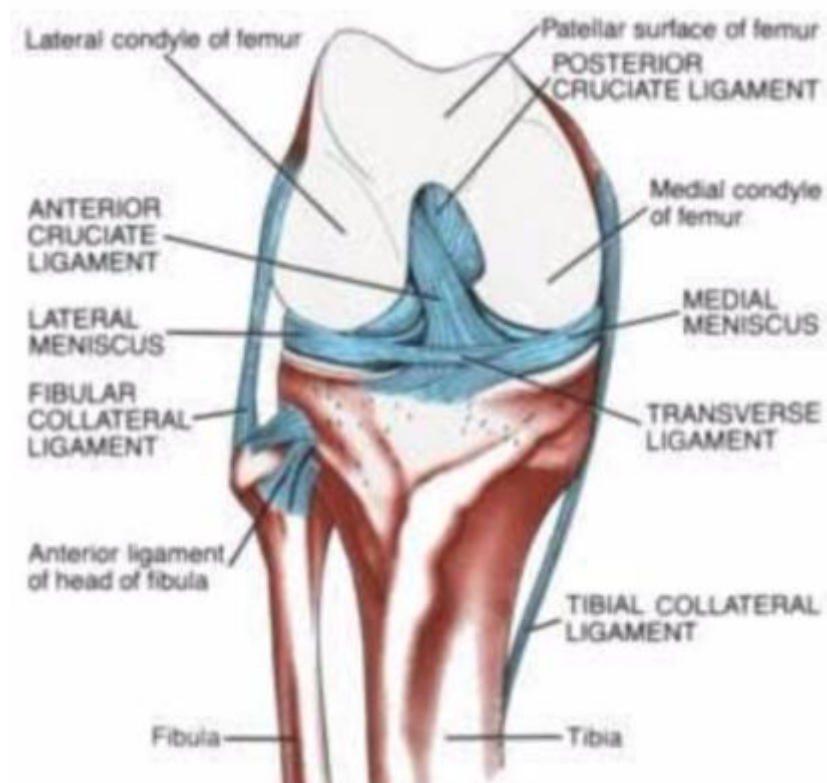
These consist of the cruciate ligaments and the menisci.

The two ligaments are

- 1) Anterior Cruciate Ligament and
- 2) Posterior Cruciate Ligament

They provide stability in the sagittal plane. Both are intracapsular. ACL is intrasynovial where as PCL is extrasynovial.

LIGAMENTOUS STRUCTURES



Anterior Cruciate Ligament:

It is made up of bundles of fibres, which gets taut in varying degrees of knee flexion and extension. The average length of ACL is 3.8 cm and the average width is 1.1cm. The tibial attachment is in front of anterior tibial spine. It is the primary stabilizer against anterior displacement of tibia.

Posterior Cruciate Ligament:

It is the primary stabilizer against posterior translation of tibia over the femur. It is almost vertical in its alignment in sagittal plane. In the coronal plane it passes obliquely upwards and medially to its femoral attachment. The length of PCL is 3.8 cms and the width is slightly bigger than ACL about 1.3 cms.

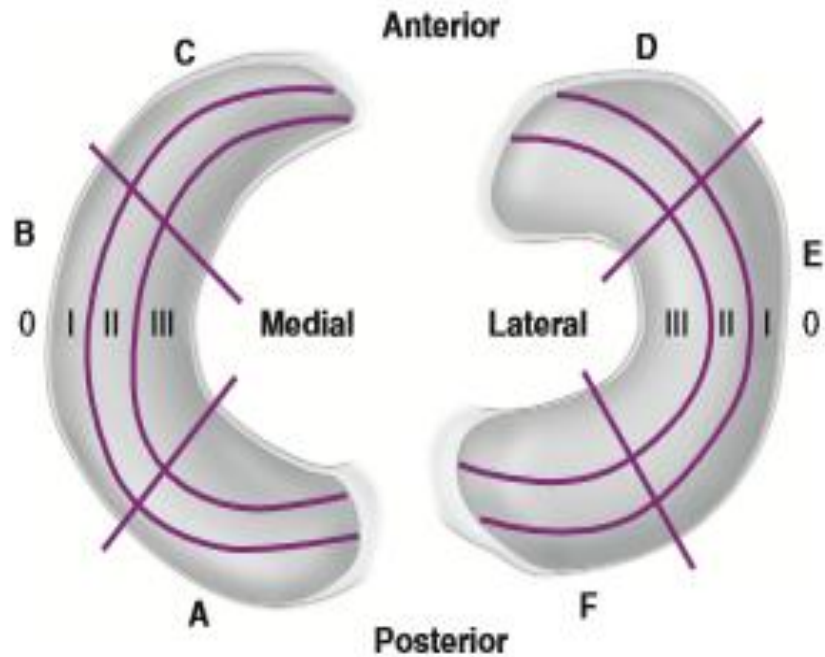
The two cruciate ligaments complex is taut in all degrees of knee motion and maintains contact pressure between femoral and tibial condyle.

MENISCUS:

- 1) Medial meniscus
- 2) Lateral meniscus

Medial meniscus:

Medial menisci is “c” shaped where as lateral menisci is circular. The menisci are crescents, roughly triangular in cross section. It is composed of dense, tightly woven collagen fibers arranged in a pattern providing great elasticity and ability to withstand compression. The anterior horn is attached firmly to the tibia anterior to the intercondylar eminence and to the anterior cruciate ligament. The posterior horn is anchored immediately in front of the attachments of the posterior cruciate ligament posterior to the intercondylar eminence. Average width is 10 mm and the thickness is 3-5 mm. Meniscus is anchored to the tibia by the coronary ligaments.



Lateral meniscus:

Lateral meniscus has more of tibial surface than medial meniscus and posteriorly attached in the intercondylar area to the femoral condyle by anterior and posterior menisiofemoral ligaments. Lateral meniscus is 5 mm thick and width of 10 mm.

FUNCTIONS OF MENISCUS:

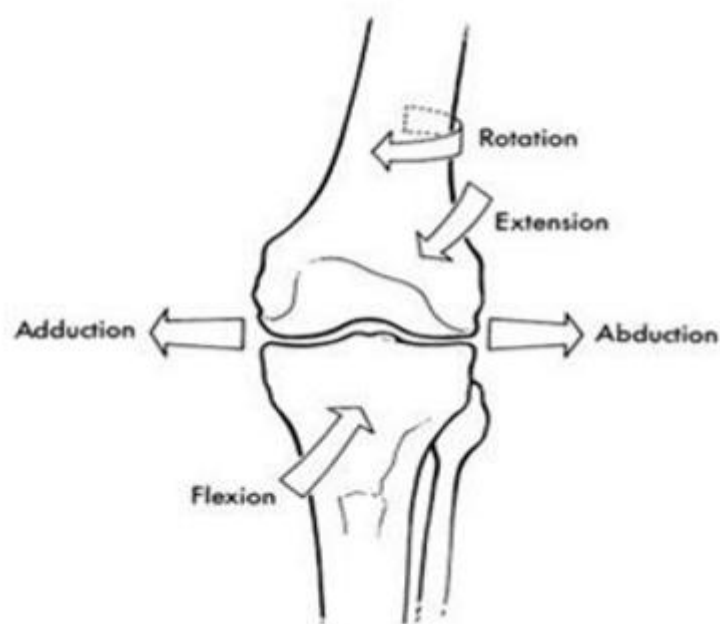
- 1) Essential for normal function of the knee joint.
- 2) Act as a joint filler
- 3) Prevent capsular and synovial impingement
- 4) Joint lubrication function
- 5) Contributes stability.

BIOMECHANICS OF KNEE JOINT:

Functional stability of the knee is provided by both ligaments and muscles around the knee.

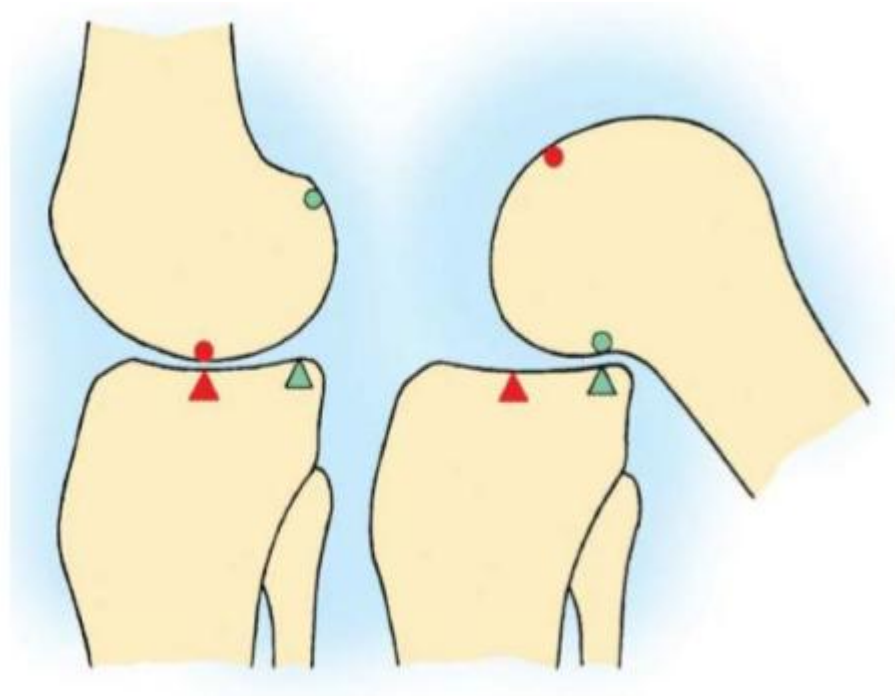
A. KINEMATICS:⁵⁸

1. Range of movement of the knee ranges from 10 degrees of (recurvatum) hyperextension to 130 degrees of flexion. Functional range of movement is from 0 - 90 degrees of flexion. Rotation varies in relation to position of flexion. Only minimal rotation is noted when the knee is in extension.



2. **Joint motion:** Flexion and extension involves both rolling and gliding motions. The femur gets internally rotates during last 15 degrees of extension (“Screw home” mechanism). Posterior roll back of the femur

on the tibia during flexion increases maximum knee flexion. The axis of rotation of the intact knee passes through medial femoral condyle.



Contact points generated by gliding and rolling motions.

B. KINETICS:⁵⁸ Extension is by the quadriceps mechanism, through the patellar apparatus; the hamstring muscles are primarily responsible for flexion at the knee.

1. **Knee stabilizers:** - Ligaments and muscles of the knee play a major role in knee joint stability.

2. **Joint forces:-**

a) **Tibiofemoral:** Articular surfaces are subjected to a loading force which is equal to three times the body weight in level walking and up to

four times more while climbing steps. The meniscus also involved in load transmission.

b) **Patellofemoral:** Patella plays an important role in knee extension by increasing the lever arm. Loads are proportional to the ratio of quadriceps force to knee flexion. The quadriceps provides an anterior subluxating force at 0-45 degrees range of motion.

3. **Axis:-**

a) The mechanical axis: - Centre of the femoral head to centre of ankle

b) Vertical axis: Centre of gravity to ground

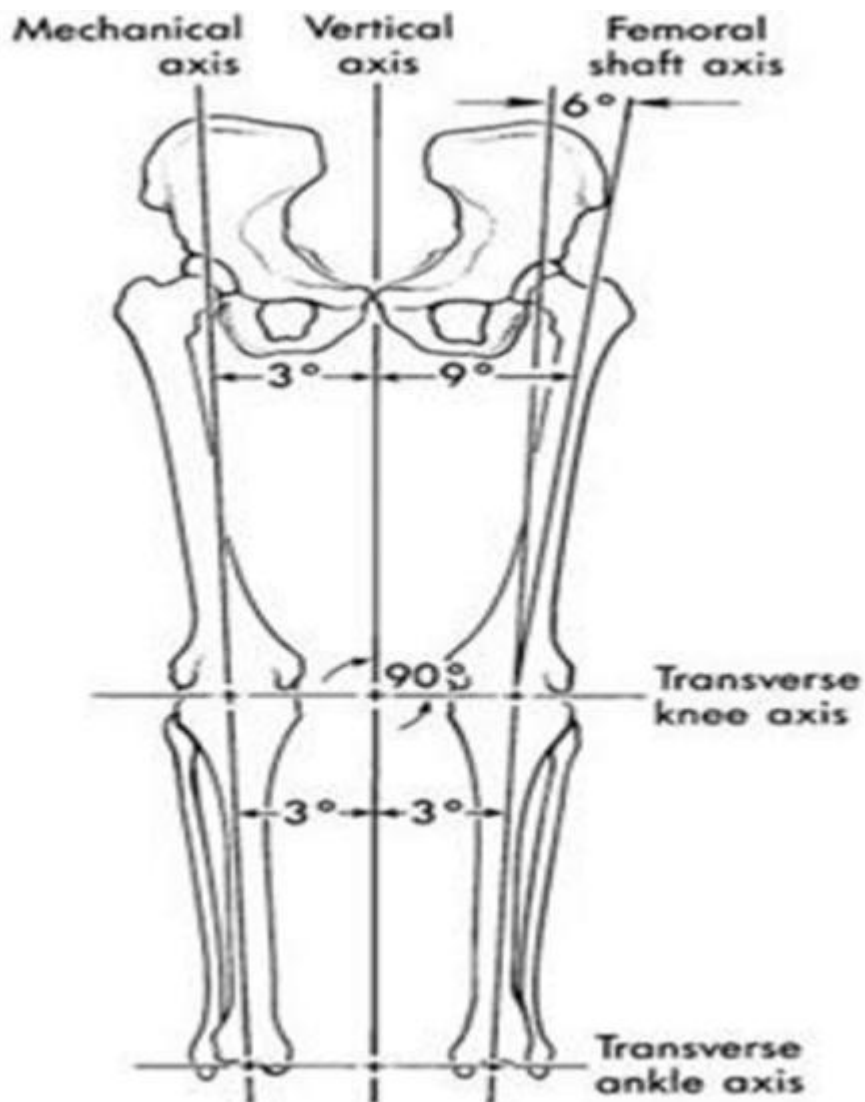
c) Anatomic axis: along the long axis of femur shaft and tibia.

Relationships:-

Mechanical axis is at 3 degrees valgus from vertical axis.

Anatomic axis of femur has 7 degrees of valgus from mechanical axis.

Anatomic axis of tibia is at 2-3 degrees varus from mechanical axis



In normal stance 75 – 90 % of load is shared on the medial portion of the knee.

Surgical and Applied Anatomy:

Fracture patterns in the tibial plateau are dictated by the forces applied combined with the osseous anatomy of the proximal tibia. Occasionally, muscle forces or ligament attachments play a role in the fracture pattern.

The tibia gradually flares from the relatively narrow diaphysis to the proximal tibia. In the proximal part, the anterior proximal tibia widens to become the tibial tubercle, where the patellar tendon gets inserted. Above this, the proximal lateral tibia abruptly flares from the smooth anterolateral surface to form the lateral tibial condyle, which serves as the origin of the anterior compartment muscles, and more proximally has Gerdy's tubercle for the insertion of the iliotibial band. Posteriorly, the fibular head serves as a palpable landmark on the lateral aspect and provides attachment to the fibular collateral ligament and the biceps tendon. Common peroneal nerve rests on the posterior neck portion of the fibula. The proximal fibula buttresses the lateral plateau, and associated fractures of the proximal fibula result in a greater degree of valgus instability and indicate a severe lateral plateau fracture.

Angular forces and compression to the knee and axial loading forces lead to failure through these flared condyles on the lateral or medial sides

or with straight axial loading on both sides. The medial plateau is more resistant to failure than the lateral plateau.

The articular surface of the lateral tibial plateau is convex, while that of medial tibial plateau is concave. It provides greater articular congruity with the medial femoral condyle than on the lateral femoral condyle. This is important when using radiographs and fluoroscopy for surgical treatment because it allows separate assessment of the medial and lateral plateau on the lateral radiographs. The proximal articular surface slopes in relation to the shaft from the front, which is high, to the back, which is low.

In a study using MRI, **Hashemi⁵⁷ et al** found that the average values were around 5 degrees for sagittal slope and 3 degrees for coronal slope. However, these angular relationships of the tibial plateau had significant variation between individuals, with the range of varus coronal slope between -1 and +6 degrees and the sagittal slope from 0-14 degrees on the lateral side and -3 to +10 degrees on the medial side.⁵⁷ These variations between individuals are important for improving the outcome tibial plateau fracture surgery since small degrees of mal-alignment may be considered important. Assessing alignment in comparison to the non-fractured side is prudent.

Articular surfaces are covered by hyaline cartilage and are partially covered by the fibro-cartilaginous menisci, both of which are attached to their respective plateaus by the meniscotibial ligaments (coronary ligaments). There is greater meniscal coverage of the lateral plateau than the medial plateau. The intercondylar eminence, medial and lateral tibial spines, which are nonarticular, separate the two plateaus. They also serve as attachment for the ACL and PCL.

The proximal anterior aspect of tibia is subcutaneous, while posterior tibia is deep beneath the structures crossing the popliteal fossa, making direct surgical exposures in this area difficult. The anterior tibia is more accessible but particularly the medial surface is at risk for surgical incisions in high-energy fractures. The pes tendons, gracilis, sartorius, and semitendinosus insert on the anteromedial aspect of the proximal tibia just distal to the insertion of the patellar tendon on the tibial tubercle. Before insertion, these tendons give off expansions to the fascia of the lower leg. The posterior aspect of the pes expansions must be incised and retracted anteriorly during the posteromedial approach.

The anterior compartment muscles, tibialis anterior and extensor digitorum longus, arise from the inferior surface of the lateral condyle of the tibia. The origin must be elevated to place an anterolateral tibial plate. The medial head of the gastrocnemius arises from the posterior aspect of

the femur just above the posterior medial femoral condyle. It can be retracted laterally or, if necessary, the origin can be incised to enhance exposure of the posteromedial and posterior tibial plateau.

The common peroneal nerve runs under the cover of the biceps femoris and winds around the neck of the fibula. It is not at risk during most surgery for tibial plateau fractures as long as the surgeon is aware of the position of the fibula. Posterolateral approach may be chosen rarely in which case the peroneal nerve must be identified and mobilized. It is at risk from direct lateral impact mechanisms and with high-energy fractures of the tibial plateau, particularly medial plateau fractures which produce varus alignment.

The popliteal artery rarely gets injured in tibial plateau fractures. However, the trifurcation of the popliteal artery occurs in an area where plateau displacement is likely with certain fracture patterns and the anterior tibial artery is bound at the interosseous membrane and is at particular risk in shaft-dissociated patterns. Occult injury to the anterior tibial artery may account in part for the compartment syndromes frequently associated with these fracture patterns.

In late 1970s, improved techniques of operative reduction and internal fixation of tibial plateau fractures became more common. They had the advantages of maintaining the articular surface, aligning the

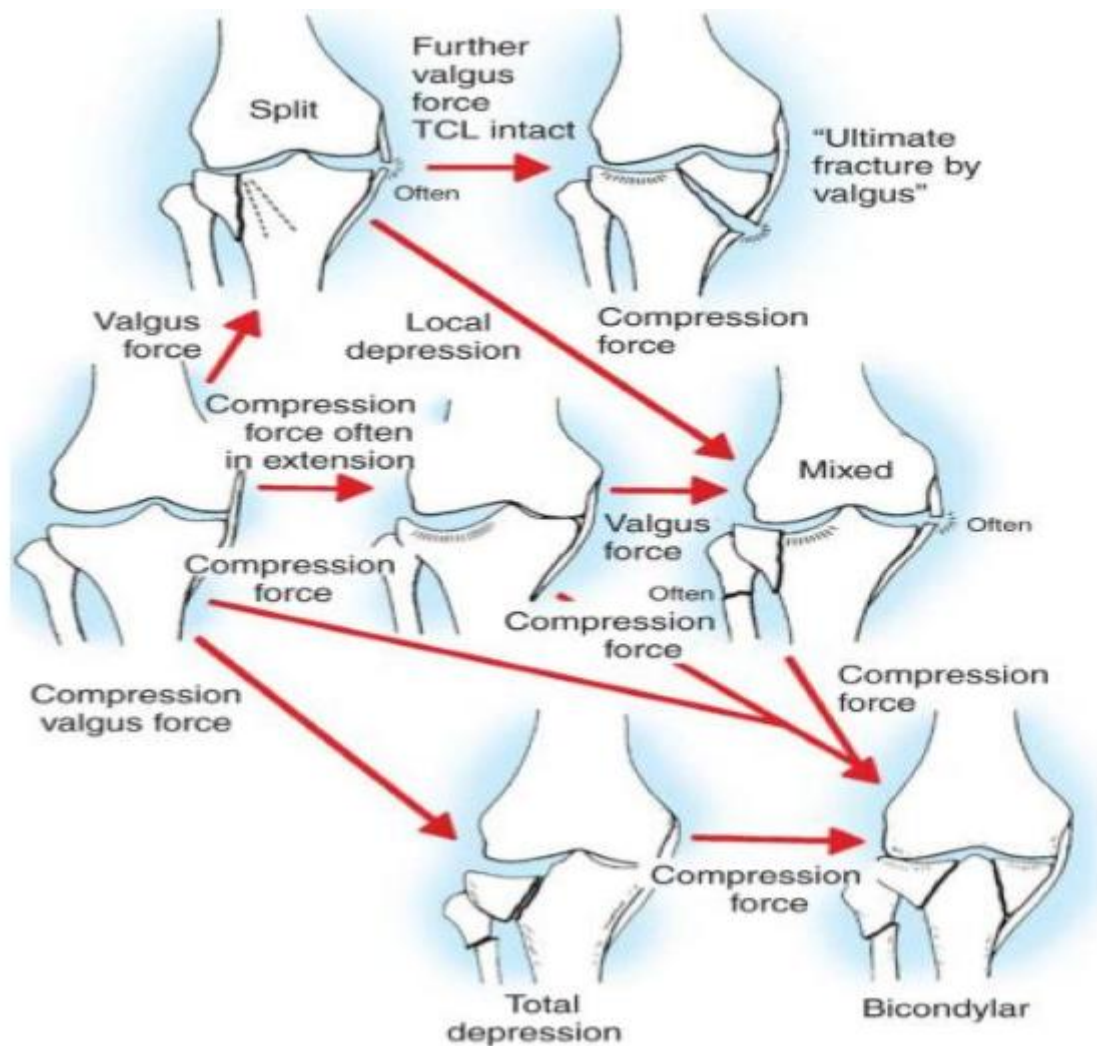
fracture fragments and early knee mobilisation after injury with less-encumbering external fixation.

Similar to non-operative treatment in management of tibial plateau fractures, better results were reported with the use of internal fixation for the majority of patients.⁵⁹⁻⁶¹ Criteria were developed for internal fixation of proximal tibial fractures but this is controversial even today. Different criteria were used for fixing the fracture depending upon the surgeon's choice.⁶²

Drennan D.B²⁴ et al in 1979 reviewed 61 displaced fracture of tibial plateau treated by closed manipulation, reduction and immobilization for 6 weeks in a well moulded hip spica. He observed that 85% of patients achieved good or excellent results objectively.

Fracture classification is of immense important in defining the fracture pattern and to select optimal operative procedure. Tibial plateau fractures were most commonly treated surgically. Surgical complications were relatively more common. So, various modifications in surgical techniques of reducing and fixing the fractures have been evolved over the last three or four decades which reduces the complications following fixation of the tibial plateau fracture.

MECHANISM OF INJURY



IMAGING TECHNIQUES

Moore and Harvey²³ in 1974 demonstrated the use of tibial plateau view with xray directed at angle of 105° to the tibial crest. This permits more accurate assessment of the initial depression of the articular surface.

Standard Anteroposterior and lateral views are taken. Radiographs will not give more information about the fracture fragments. Nowadays,

there are latest techniques leading to better understanding of the fracture pattern which helps in treatment and early mobilisation of the knee with excellent outcomes for patients with tibial plateau fractures.

3 Dimensional CT helps to identify the fracture pattern which is very useful to plan preoperatively for fixing those complex fractures.⁶³ These modalities also help in proper selection of implants.^{64,65}

J. J. Dias¹⁰ et. Al in 1987 recommended CT scan for evaluating the degree of comminution, for classifying and measuring the displacement of fracture fragments.

MRI also helps in assessing the soft tissues, ligaments and meniscus around the knee.

Fractures that involve both tibial condyles with shaft instability requires locking plates fixation which provide fixed angular stability. Locking plate gives more stability and is used, if instability is noted. If fixation is needed for both the condyles, separate surgical exposure provides better results than extensile approach.

In case of high velocity injury with displacement and extensive soft tissue damage, joint-spanning external fixation has helped in achieving the length and alignment. It also helps in achieving faster recovery of the soft tissues.

In case of split with depression fractures, new imaging techniques are being used to visualise the reduced articular surface which helps in selecting the implants and proper positioning of the implant in order to fill the defect in the metaphyseal region after reducing the fracture. These new imaging techniques are important because loss of articular surface may lead to early degenerative arthritis.

The AO classification is based on the anatomical distribution of fracture pattern and is the key international classification of fractures which is universally accepted.

CLASSIFICATION:

AO/OTA Classification:

The AO/OTA alphanumeric code for articular fractures is well suited to the proximal tibia.⁶⁶ It has several advantages over the commonly used Schatzker classification. It identifies both articular and nonarticular fractures and provides a way to distinguish proximal tibia from tibial shaft fractures.⁶⁷

The rule of squares identifies a proximal tibia fracture as one where the center of the fracture is within a square with one side along the articular surface and the length of a side defined by the width of the metaphyseal segment. Fractures outside of this square are tibial shaft fractures. There is more than one category of medial plateau fracture, which is desirable because it is clinically important to distinguish subtypes of medial plateau fractures for treatment. For the total articular C patterns, the degree of comminution of both the metaphysis and the articular surface is subcategorized, providing important distinctions for treatment and prognosis.

The AO/OTA classification therefore distinguishes ranges of severity in high-energy patterns better than the Schatzker classification. It is well accepted for trauma databases and has been frequently used in

recent publications on tibial plateau fractures.⁶⁸⁻⁷¹ It is increasingly becoming a standard and well-accepted way to classify proximal tibia fractures.

The entire classification was recently updated and republished, and there were no changes made to the proximal tibia section.⁶⁶

Type A: These are nonarticular fractures of the proximal tibia. Technically, they are not tibial plateau fractures because the articular surface is not involved.

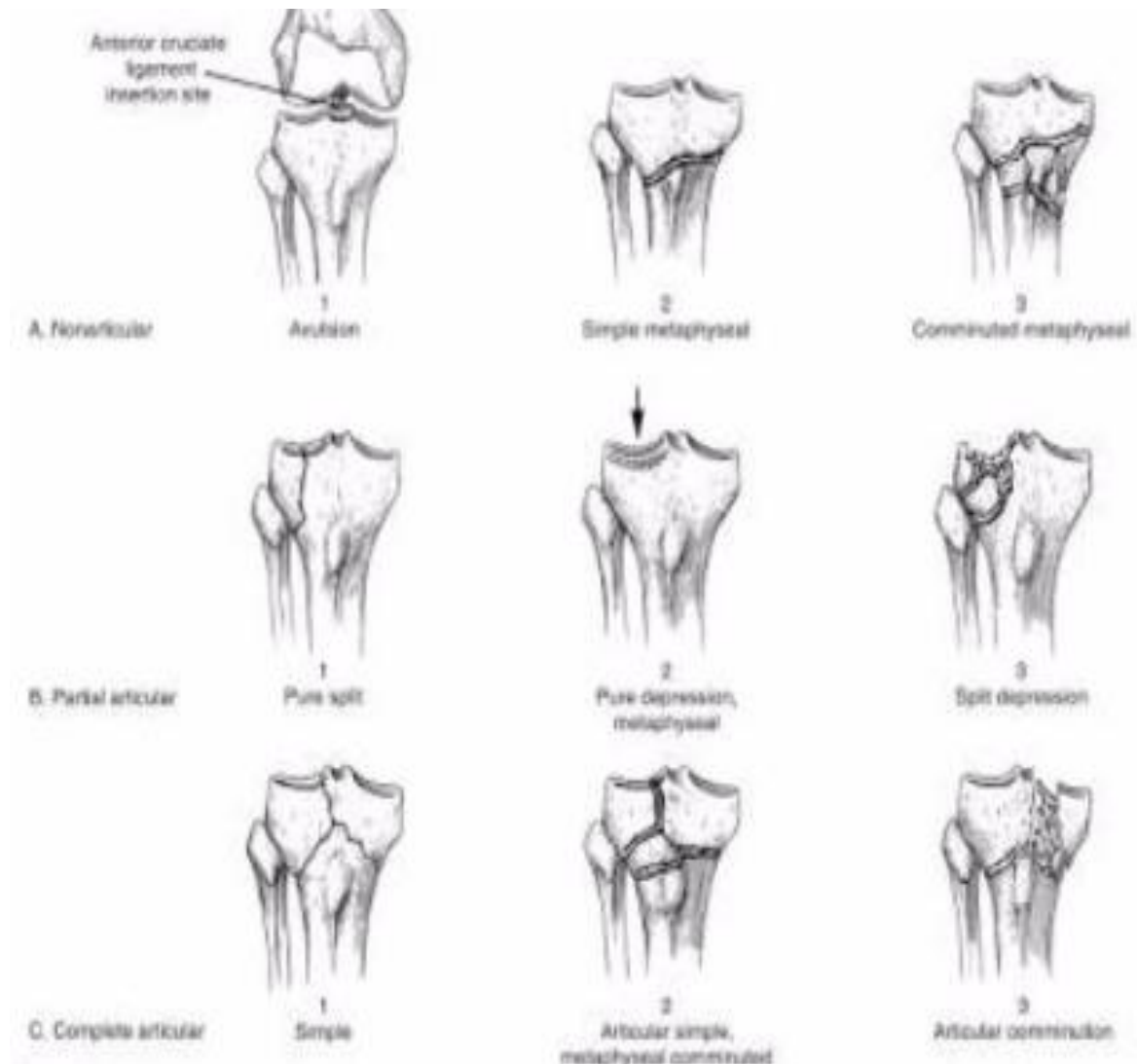
Type B: These are partial articular fractures. Although this terminology applies well to the tibial plateau, it is not commonly used because the verbal descriptions of split and split depression are more common. However, these are lateral side terms and the AO/OTA classification allows similar, although less common, medial side injuries to be classified.

B1—Simple articular split

B2—Split depression

B3—Comminuted split depression

AO CLASSIFICATION



Schatzker and McBroom⁹ in 1979 considered that open reduction with proper anatomical restoration of articular congruity of the knee produces best results. In their study out of 70 patients, they obtained 78% acceptable results in the operated group as compared 58% in the non operated group.

Schatzker classification is based on plain radiograph.

SCHATZKER CLASSIFICATION OF TIBIAL PLATEAU FRACTURES

TOTALLY SIX TYPES

1. Lateral condyle split fracture
2. Lateral condyle split with depression
3. Pure central depression
4. Medial plateau fracture
5. Bicondylar fracture
6. Bicondylar fracture with metaphyseal extension.

1. TYPE I - LATERAL CONDYLE SPLIT FRACTURE



- Valgus abduction along with axial compression force

2. LATERAL CONDYLE SPLIT WITH DEPRESSION



- Valgus abduction and compression force.
- Lateral plateau split with depression into the metaphysis.

3. PURE CENTRAL DEPRESSION



- Pure central depression noted in the articular surface.

4. MEDIAL CONDYLE FRACTURE



- Varus adduction and compression force.

5. TYPE V BICONDYLAR SCHATZKER FRACTURE



- Axial compression fracture.
- Both condyles are fractured.
- Continuity maintained between metaphysis and diaphysis.

**6. TYPE VI TIBIAL PLATEAU FRACTURE WITH
METAPHYSEAL AND DIAPHYSEAL EXTENSION.**



- High velocity injury with valgus or varus compression force.
- Severe comminution.
- Fracture of proximal tibia that dissociates metaphysis from diaphysis.

Bowes²⁵ in 1982 and Hohl reviewed 52 out of 110 tibial plateau fractures for more than one year. Non surgical treatment was used in 72% of fractures; cast in 51% and traction in 21% ORIF was used in 28%. Overall results were acceptable in 84% of patients. They mentioned the use of cast bracing in 31% of cases either as a primary treatment or after open reduction.

The fracture-dislocation patterns classified by Hohl and Moore

Type I—coronal split fracture.

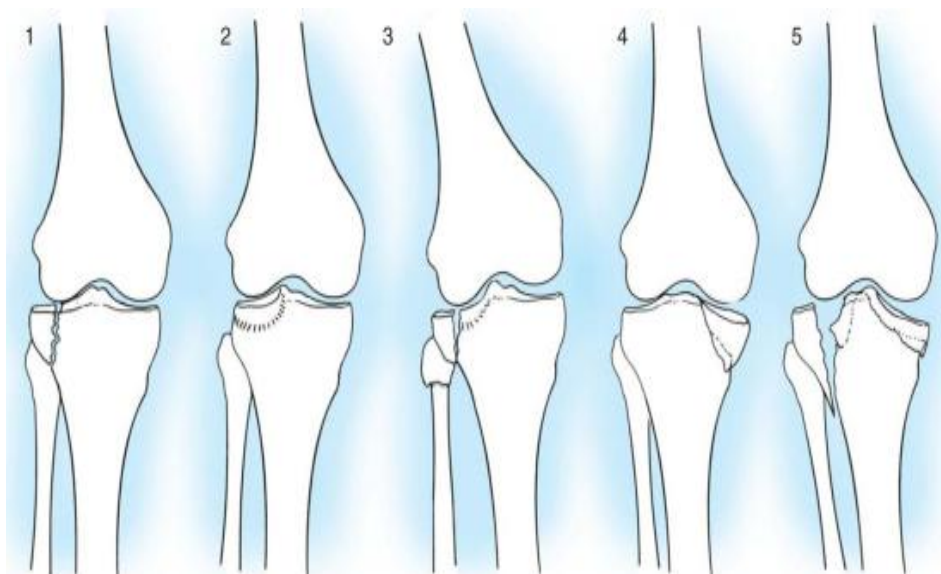
Type II—entire condyle fracture.

Type III—rim avulsion fracture.

Type IV—rim compression fracture.

Type V—four-part fracture.

Hohl and Moore



VARIOUS TREATMENT OPTIONS:

A. Closed Manipulation

The technique of close reduction is usually combined manoeuver. Very difficult to reduce by closed reduction. Combined manoeuvre includes traction to the leg, adduction or abduction at the knee and sometimes lateral compression for more severely displaced fractures. The force of such manipulations may be augmented by using a traction table and compression clamp.

Paul J. Duwelius³⁶ et al used heavy longitudinal fraction applied with the patient on a fracture table. An assistant applies varus loading to the knee. The depressed tibial plateau margins are elevated by ligamentotaxis or by the pull of capsule and ligaments attached to the fragments. Closed reduction is often successful in type I, IV and V fractures which have no articular surface depression. An above knee plaster cast is applied for six weeks and check xray is taken. Mobilization started at six weeks and weight bearing is delayed till the evidence of union is seen radiologically, usually by 12 weeks.

The underlying assumptions for maintaining the reduction in plaster presumably³⁶ are

- 1) Osteoarthritis of the joint will inevitably follow a fracture, unless the reduction is perfect and is perfectly maintained by rigid immobilization until union is complete in radiograph.
- 2) Rigid immobilization of the fracture is necessary to permit healing of associated ligamentous damage.

The fracture is maintained in an above knee plaster cast for about six weeks. Then plaster is removed and mobilization of the knee joint is allowed, the limb is maintained non weight bearing until about 10 to 12 weeks, when radiography shows good evidence of union and after that started on weight bearing.

Delamarter. R, Hohl.M²⁸, in 1989 analyzed 306 proximal tibia fractures of which 141 patients were treated with application of cast brace as the primary form of treatment or after open reduction or traction. They followed 91 patients in whom 85% of patients had maintained fracture position. 82 patients maintained fracture alignment with less than 5 degrees of mal-alignment. They concluded that cast brace could be effective in all types of tibial plateau fractures and can allow early mobilization and in some cases, weight bearing also.

Jensen S²⁹ et al in 1990 evaluated long term result of 109 tibial fractures. Skeletal traction was applied for 61 patients and early knee

movement and surgery was done for 48 patients with average follow up of 70 months. They concluded that conservative treatment is valid, if surgery is not feasible in those cases.

Honkanen S. E and Jarvien M.J³⁰ in 1992 analyzed 131 fractures of tibial condyles in 130 patients. 55 (42%) fractures were treated conservatively and 76 (58%) were treated operatively. In conservatively treated cases, 49% of patients had acceptable subjective results. Functional results in 60% and Clinical result in 52.7% cases. In operative cases they were 57.9%, 73.7% and 52.6% respectively.

Duwelius and Connolly³⁶ found that patients with tibial plateau fractures treated by closed reduction with or without percutaneous pin fixation showed 89% rate of good clinical results who were mobilised with cast brace. Spica casting following closed reduction showed good and excellent results in 85% of patients. Hence, Cast bracing was mostly used for proximal tibial fractures as an isolated treatment.

B. Skeletal traction with early mobilization

Traction and exercises without fixation is simple and satisfactory in the management of tibial plateau fractures. Traction for tibial condyle fractures usually allows good early motion of the knee but in most of the

cases, deformities and instability occurs that leads to early arthritic changes of the joint.

The technique of treatment:-

Under anaesthesia, the knee joint is aspirated, if there is any collection and compression dressing applied. Fracture is reduced by using longitudinal traction through a Steinmann pin inserted 1 or 2 inches below the fracture. Traction of about 10 lbs is applied and the foot end of the bed is raised on blocks. Quadriceps strengthening exercises should be started within the traction itself. Within a few days knee mobilization exercises are started, once the patient is able to raise the leg from the bed. At six weeks traction is removed and the patient is started non weight bearing mobilisation for six weeks after which gradual weight bearing is started.

The method of traction and knee exercises permits movement without allowing abduction strain so that any associated damage to the medial ligament is able to heal.

Blokker²⁶ et. Al in 1984 reviewed 60 tibial plateau fractures. Of which 38 TPF's were treated by open reduction and internal fixation and closed reduction was done for 22 patients. Satisfactory results were noted in 75% of the patients. Proper reduction of the fracture is an important

factor in predicting the outcome. Achieving proper reduction and the immobilization period of the knee was not crucial.

Tscherene and Loben¹² in 1993 studied 190 out of 255 cases and concluded that open reduction and internal fixation with proper reconstruction of the articular area, rigid fixation of the fracture fragment and allowing early knee mobilisation achieved good results even in extremely difficult fractures after open reduction.

C. Closed reduction with percutaneous cancellous screw fixation:

Displaced type I and IV fractures which have no articular surface depression and are reducible by closed methods and percutaneous screw fixation done. Preoperative MRI and arthroscopy is very helpful in recognizing any meniscal injuries and any articular surface depression if present. Image intensifier is mandatory in accurate placement of implants.

D. Extensile exposure of the joint following arthrotomy and reconstruction of articular surface and stabilization with

- 1) Cancellous screws
- 2) Buttress plate and screws

Augmentation done with bone grafts, cancellous bone grafts from iliac crest are commonly used as and when required.

The aim of open reduction is to attain perfect anatomic reduction of the articular surface and rigid internal fixation. There is no literature suggesting about the amount of depression or plateau step off that indicates the need for operative treatment. All authors agree that depressed articular fracture fragments will not change by manipulation or traction alone.

An important factor affecting long term prognosis is the ability to maintain the normal alignment of the femoral condyle over the tibial plateau.

Rasmussen and colleagues²² demonstrated a high co-relation of condylar widening and articular incongruity between the tibial plateau and femoral condyles which results in posttraumatic arthritis. Malalignment of the tibial plateau with respect to the tibial shaft affects the functional outcome after fracture fixation.

Open reduction and internal fixations with locking plates and screws or external fixation is the treatment of choice for displaced incongruous, unstable or mal-aligned tibial plateau fractures. Preoperative planning is very important for achieving the necessary aims. Multiple paper drawings are helpful to arrive at optimal fixation of the fracture and also clarify the need for supplemental bone grafts and availability of proper implants.

Absolute indications for fixing the tibial plateau fractures⁷⁴ are:

- 1) An open fracture
- 2) Acute vascular injury
- 3) Associated compartment syndrome
- 4) Irreducible fractures

All types of fractures which are not reducible by closed methods, are reduced by exposing the fracture using appropriate approach depending upon the type of fracture and visualizing the reduction by an inframeniscal arthrotomy. Depressed articular fragments are elevated through a cortical window (in type III) or by retracting the split condyle fragment (in type II) and the resultant defect filled with autogenous bone grafts, bones from bone bank or bone graft substitutes (hydroxylapatite) and the fragments are fixed with cancellous screws or a buttress plate.

Type IV Schatzker fractures are usually unstable which requires open reduction and internal fixation with medial buttress plate if required.

Complex tibial condyle fractures that include both type V and type VI fractures are usually treated by open reduction and internal plate fixation. If there is severe swelling limb should be monitored for compartment syndrome. The amount of comminution and the soft tissue trauma should be evaluated prior to open reduction to avoid late complications.

Barei, Nork, Mills,¹¹ et al in 2006 studied 83 bicondylar fracture treated with dual plate fixation through two separate exposures. Out of 83, 23 male and 18 females with mean follow-up of 59 months were included in the study. Two patients had deep infection. Satisfactory articular congruity was achieved in seventeen patients (55%), satisfactory coronal alignment was achieved in 90 % of patients and 31 patients had satisfactory tibial plateau width. They concluded that articular congruity reduction was associated with a better functional assessment score. Hence, dual plate stabilization of severely comminuted bicondylar tibial plateau fracture through separate surgical approach results in better outcome.

According to **Douglas R. Dirschl, and Daniel Del Gaizo¹**, in April 2007, High velocity injuries should be assessed carefully in order to provide better outcome and avoid complications in tibial plateau fractures. They assessed the patients with complete history and physical examination. Clinical examination of the patient includes whether the limb was swollen or not. Lacerations, blisters, deformity, angulations and distal perfusion should be noted. Patients were closely monitored for compartment syndrome. Radiographs AP and lateral views were taken. CT was taken to classify and to clearly visualize the fracture pattern and to plan accordingly. Knee spanning external fixation helps in correcting the limb length disparity. Definitive fixation is usually carried out after one

week since injury. Achieving articular congruity was very important in managing these fractures. Spanning external fixation should be left in place until definitive internal fixation of the fracture has been completed. In this study limited open reduction and internal fixation was mentioned using small incisions, indirect reduction via reduction aids (clamps, probes, etc) which limits the injury to soft tissues. In case of bicondylar fracture dual plating was done. Locking plates increases the stability of complex proximal tibial plateau fractures. The current practice was mainly to wait until the soft tissue injury to subside and plan for definitive fixation to use minimally invasive plating techniques. In case of tibial plateau fractures with extensive soft tissue injury treatment is targeted in a staged manner involving soft tissue care in order to reduce the complications.

According to **V. Musahl⁴ et al, from the University of Pittsburgh, Pittsburgh, USA**, in 2009, proximal tibial fractures has been placed on the strict adherence to the principles of perfect reduction, stable fixation and early mobilisation of the knee. In this study the value of single incision and MIPPO technique was discussed. In case of bicondylar fractures, dual plating was used.

In this review article a study done by **Gosling⁷² et al** out of 69 TPF's, deep infection was noted in one case treated by unilateral locking plate. Indication for using locking plate includes highly unstable fractures,

osteoporosis and those with comminution. Laterally fixed locking plate provides more stability if there is comminution noted in the metaphyseal diaphyseal region. So, there won't be any need for the additional plate. This allows fixation through single lateral plating. Higher rate of malalignment was noted in proximal tibia fractures when using LISS system.

In their study, **Z.Yu,L.Zheng¹⁴ et al, in 2009**, considered double buttress plate fixation of bicondylar and highly unstable tibial plateau fractures is a better option. Double buttress plating provides better stability and prevents extensive soft tissue damage which facilitates early mobilisation of the knee.

In 2010, **Jain D⁷ et al** performed operative intervention within 24 hours of presentation in all except four cases who had closed fractures with extensive soft tissue edema and impending compartment syndrome. MIPO technique was used in ten cases out of which eight cases where fracture reduction was easily achieved with indirect reduction were fixed with smaller plates and two cases where long plates were used for fractures extending into tibial diaphysis using the bridge mode. The average time for operative intervention in these patients was seven days (range five to ten days).

In 2012, According to **CC Chan, J Keating**¹⁷ reported minimally invasive internal fixation for tibial plateau fractures have become popular. LISS plate system provides better stability in case of complex bicondylar tibial plateau fractures in which knee range of motion can be started early. Unilateral locking screw plate (LSP) is very effective as double plating for bicondylar tibial plateau fracture which is a good choice for patients with a large posteromedial fragment in bicondylar tibial plateau fracture.

In 2013, **Albuquerque**¹⁶ **et al**, in their study found that most patients who suffer tibial plateau are male, around the fifth decade of life, mostly victims of road traffic accidents with depression type bicondylar fracture. Due to the lack of MRI images, associated injuries were uncommon in our study. The adoption of preventive measures such as educational campaigns, surveillance and traffic education, and the inclusion of sensitive imaging methods in major trauma centers such as CT and MRI can respectively reduce the number of injuries and improve patient care of tibial plateau fractures.

In 2013, Kye-Youl Cho⁵ **et al**, studied twenty three patients who belongs to type V and VI tibial plateau fractures between September 2007 and June 2010. Single plate or screw fixation was used for 13 patients and the remaining 10 patients with use of a longitudinal midline incision and fixation of the fracture with dual plates. Satisfactory functional and

radiological outcome was noted in this study. In case of highly unstable complex fractures, single midline incision with dual plating was considered. Evaluation was done and clinical and radiological outcomes assessed. Mean VAS score was 2.2 at final followup and American knee society score was found to be 85. The average knee range of motion was 122.5 degrees. The main drawback of LISS method does not provide more stability as compared with dual plates.

Rakesh Sharma⁶ et al, in 2013 published 40 cases of tibial plateau fractures which were randomly divided into two groups of 20 patients each. Group A was treated by traditional buttress plating while group B was treated by MIPO technique using lateral locking plate. MIPO technique is a better technique compared to traditional plating as it involves smaller incision, lesser soft tissue dissection and a much stronger construct. This in turn leads to lesser complications with early functional recovery. Smaller incisions, lesser soft tissue dissection, lesser bleeding and strong implant construct allows us to do internal fixation even in compound fracture type 1 and 2 where otherwise, we have to wait for a long time in case of traditional plating. Because of a stable and strong construct, a simple locking plate is sufficient in majority of cases while dual plating may be required in many comminuted proximal tibial fractures treated by buttress plating. Early rehabilitation, fewer complications, early

weight bearing and better and complete functional recovery is seen with MIPO technique.

In 2014, Meng-Hsuan Lee² et al reported Tibial condyle fractures (TPF) of complex patterns involving articular depression and displacement. They followed up the surgical outcomes of tibial plateau fractures treated by,

- A) Unilateral locking plate,
- B) Classic dual plates and
- C) Hybrid dual plates for TPF.

They reviewed 76 Tibial Plateau Fractures of Schatzker type V and VI retrospectively who we operated from June 2006 to May 2009. Exclusion criteria were patients who expired due to other medical comorbidities and patients who were not on complete follow-up. 45 patients were selected out for the study. They were categorised based on the implant used for the fixation of tibial plateau. Group I consists of 15 patients who were treated with unilateral locking plate. Group II consists of 19 patients, treated with classic dual plates. Rest of the 11 patients belonged to group III who were treated with hybrid dual plates. Postoperatively patient was followed up for a period of six weeks to 18 months. 13 patients in group I achieved solid bony union with better

results, normal range of motion were achieved without mal-alignment. 25 patients in group II and III attained same results. Open reduction and internal fixation with dual plating was very effective for stabilisation after reduction in severely comminuted unstable fractures. In case of bicondylar fracture unilateral locking plate was used, which reduces the risk of damage to the soft tissues and infection. In their study of 140 patients there were 141 TPF's. 45 bicondylar TPF's (V and VI) were followed up which met the criteria for the study. 15 TPF's were fixed with unilateral locking plate, Classic dual buttress plate was used for 19 patients and Hybrid dual plates for 11 patients. Loss of reduction was noted in 3 patients of 12 months follow up, each with unilateral locking and classic dual plates. In hybrid dual plates, loss of reduction was noted in 1 case. Complicated fractures were treated using specially designed locking plate and screws. Soft tissue healing should always be kept in mind. Single locking plate approach for TPF's minimizes soft tissue damage, surgical time, hospital stay period and wound infection.

In 2014, **Mohammad Ali Tahririan¹³ et al** reported the functional outcome of proximal tibial condyle fractures with locking and non locking plate. In this study, twenty patients were treated by locking and non locking plate was used for twenty one patients. Outcome was assessed using knee society score for both locking and nonlocking plate separately.

Mean range of motion for locking and nonlocking plate was found to be 122.35 and 115.71 degrees respectively. Mean knee society score was found to be 80.20 for locking and 72.52 for nonlocking.

Jackson A. Lee³ et al, in may 2006 found that 36 tibial condyle fractures in 35 patients were treated by less invasive stabilisation system (LISS). Mean age in the study group was 42 years. The average time for fracture healing was noted at 4.2 months (3–7 months). Only 2 patients had deep infection. 6° of varus was noted in one patient and seven patients had an increased articular surface angulation of 6° (4–8°) in the sagittal plane. Loss of reduction, non-union, or deep vein thrombosis were nil in this study. Thirty-six tibial plateau fractures in 35 patients were retrospectively studied, from 1999 to 2002. The mode of injury was an auto-pedestrian accident in 17 patients, 11 patients following motor vehicle accident, 4 patients with history of fall, two patients had a blow and one patient with gunshot injury. Standard xrays anteroposterior and lateral view for the tibia and anteroposterior, lateral, oblique views for the knee was done in all the patients at the time of admission. CT scans were performed to visualise the size and location of complex articular fragments. The fracture type was classified according to AO classification. 27 patients belonged to type C fractures and nine patients belonged to type B fractures. Two patients with compound fractures were classified according to Gustilo Anderson

classification as type I and type II, respectively. Excessive swelling and blisters were noted in three patients at the time of presentation. All patients were operated within a average time period of 12 days since injury. Surgery was done immediately as the swelling reduced. To minimise the soft tissue damage during surgery LISS plate was used beneath tibialis anterior muscle through lateral approach and provide a stable fixation of the fracture. Functional outcome of the patients treated by this plate was compared with other methods. 8% infection rate was found in proximal tibia fractures with a high rate of soft-tissue complications.

According to **Chang-Wug Oh¹⁸ et al, in 2006** reported Dual plating using minimally invasive percutaneous plate fixation provides excellent outcome in the treatment of tibial plateau fractures. The best mechanical construct for a proximal tibial fracture is double plating. Conventional plate fixation usually requires exposure of the fracture site, which may cause some soft tissue damage and increase the risk of infection. This may be reduced by minimally invasive percutaneous osteosynthesis (MIPO). They reviewed the functional and radiological outcome of double plating done through MIPO technique in 23 proximal tibial fractures. The final results were evaluated according to Rasmussen by independent observers (one orthopaedic surgeon and one clinical fellow who did not participate in the surgery). Excellent or good clinical result was found in 21 patients

(average score - 26). Fair result was found in 2 patients with associated injuries of the ipsilateral femoral condyle fracture and posterior cruciate injury respectively. The average range of knee motion was found to be 123°.

E. Arthroscopy assisted joint surface reconstruction and percutaneous screw/ external fixator stabilization.

In 2004 James H Lubowitz, Wylie S. Elson, Dan Guttman³⁵, studied arthroscopic management of tibial plateau fractures and concluded that intraarticular fracture was visualised and whether it was properly reduced or not can be assessed. It also helps in treatment of intra articular fractures to look for the articular surface congruity.

In a study done by Lobenhoffer⁷³ et al, 168 patients achieved adequate reduction by using either arthroscopy or fluoroscopy.

In case of fixing the fracture through open reduction and internal fixation, visualising the fracture needs periosteal stripping for proper reduction and fixing it. Chances of non-union and the need for bone grafting are of great concern. The invention of locking plate helps in using minimally invasive approaches for unilateral plating. Minimally invasive technique causes less soft tissue damage and reduces infection compared to ORIF.

The fractures which are amenable to arthroscopy reduction and internal fixation are type I, II and III plateau fractures. The advantages are:

- 1) Direct visualization of the intra-articular surface
- 2) Perfect reduction of the fracture
- 3) Reduces the morbidity rate compared with arthrotomy.

Arthroscopy helps in diagnosis and treatment of meniscal and ligamentous injury which permits thorough lavage to remove loose bodies. The fractures are later stabilized using percutaneous plates and screws.

F) Reconstruction of the articular surface with external fixator:

Hybrid type

Tubular type

For type V and type VI condylar fractures external fixation using half pin fixator or ring fixator used as a definitive treatment of choice. External fixator which was placed below the knee can maintain articular congruity, alignment and early mobilisation of the knee.

The advantage of this exfixator is its minimal invasiveness thus reducing the wound complications. The half pin uniplanar fixators have advantage in open plateau fractures for management until definitive fixation is done.

Associated ligamentous and meniscal injuries are treated either conservatively or by secondary repair depending upon the severity of the injury through arthroscopy or open techniques.

Marsh J. L³¹ et al in 1995, treated 21 complex tibial plateau fractures with closed reduction, fixation of the articular fragments with interfragmentary screw and application of unilateral half pin external fixators. They considered this external fixation as a satisfactory treatment for complex plateau fractures.

In 2002 Dennis P. Weigel and J. Lawrence Marsh³³, studied the treatment outcome of high-energy fracture of the tibial plateau by external fixation and the development of arthrosis at a minimum of five years since injury. 31 tibial plateau fractures in 30 patients were treated by monolateral external fixator and limited internal fixation for the articular surface. Follow-up data were obtained at a mean of ninety-eight months on twenty-four knees. Twenty patients were taken in this study. Excellent results were found in 13 patients, good in six patients and fair in 3 patients. They have concluded that high energy complex tibial plateau treated with external fixation had good prognosis 5 years since injury.

In 2003 Ali, Ahmad M.; Burton, Maria³⁴; studied the treatment outcome of displaced bicondylar tibial plateau fractures in elderly patients (>60 years). All the patients were treated with percutaneous

interfragmentary screw fixation with additional external fixator. Knee mobilisation was started early. Bony union was achieved at an average follow up 38 months. Satisfactory results were obtained in 9 patients using rasmuseen score. Radiographic malalignment was noted in three patients with valgus malunion in severely comminuted fracture. Corrective osteotomy was done in one patient and TKA was done in another patient. They concluded that ring external fixator applied in a neutralizing mode was stable and reliable technique for the management of displaced bicondylar tibial plateau fractures in elderly patients.

G) Locking plates:

Indications for locking plates are

- 1) Severely comminuted fractures
- 2) Osteoporosis

In those cases locking plate acts as an internal splint. Lateral locking plate provides stability to bicondylar fracture as an alternate method for dual plating to prevent soft tissue damage and to avoid tension.

In 1996, Kumar³² et al, described the use of bone graft from the fibula for the treatment of severely comminuted bicondylar tibial plateau fractures which cannot be treated by lag screw and buttress plate fixation.

In 2005, P. Gaston¹⁵ et al, noted that risk of residual knee stiffness at the end of one year was 20% after tibial plateau fractures and recovery of quadriceps function was incomplete at the end of one year. Only 14% of patients quadriceps function is complete at the end of one year. Elderly patients usually have a slower recovery compared to young patients.

SURGICAL APPROACHES:

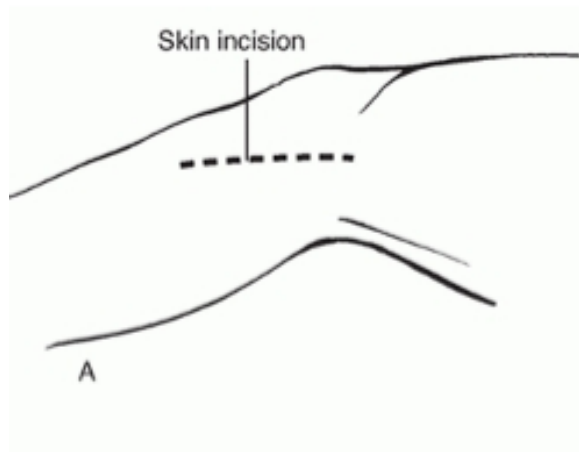
There are two frequently used surgical approaches to reduce and internally fix tibial plateau fractures. They are

- 1) Antero-lateral approach and
- 2) Postero-medial approach.

They are used in isolation for fractures on the lateral and medial tibial plateau respectively.

At present, other approaches have become unusual or reserved for special circumstances.

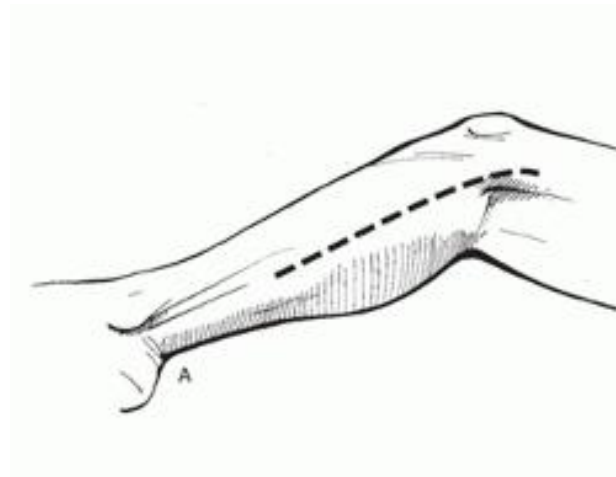
Antero-lateral Approach:



The antero-lateral approach is the most commonly used approach to reduce and internally fix tibial plateau fractures. Split depression type of the lateral tibial condyle fractures was reduced by this approach. The incision is placed over Gerdy's tubercle and is extended distally over the anterior compartment. L-shaped incision in the origin of

the anterior compartment muscles provides access to the antero-lateral surface of the tibia. While making incision over the postero-lateral border of the tibia care should be taken as the anterior tibial artery passes through the interosseous membrane from back to front. While approaching the proximal portion of the tibia, anterolateral approach is variable according to surgeon's preference. For fluoroscopic or arthroscopic reductions, the proximal exposure develops subcutaneous access posteriorly toward the fibular head for placement of a lateral tibial plateau.

Postero-medial Approach:



The postero-medial approach is used to reduce and fix the fracture on the medial side of the proximal tibia mainly the postero-medial fragment. It has got the advantage of relatively good soft tissue cover and it is widely separated from the antero-lateral approach allowing these two

approaches to be combined when necessary. Extra-articular fracture fragments are easy to reduce. Postero-medial plating is very useful to hold the large postero-medial fragment and to resist deforming forces. An anti-glide plate is placed directly over the area of maximal displacement at the apex of the fracture. The approach is based over the postero-medial border of the tibia. Supine position is most commonly used which allows access to the front of the knee for a second antero-lateral approach or to apply a distracter.⁷⁵ The leg is externally rotated, allowing easy access.

Alternatively, the patient can be positioned prone, which makes the posterior to anterior hardware easier to place and facilitates fracture reduction by knee extension.

The subcutaneous dissection must avoid the saphenous nerve and vein, and the incision must be posterior enough to allow plate to be placed on the posterior aspect of the tibia without the skin flap obstructing the screw paths. The deep interval is between the posterior border of the pes anserine and the medial head of gastrocnemius. A retractor which was placed underneath the medial head protects the popliteal fossa structures. Exposure is increased by splitting the medial head of gastrocnemius. Popliteus muscle origin is lifted and retracted laterally which helps in direct visualisation of the fracture.

Antero-medial Approach:

The antero-medial tibial plateau is easily accessed through similar to a total knee approach. However, it is unusual for fracture patterns to involve the antero-medial tibia in isolation. An anteromedial approach should not be used in conjunction with the common anterolateral approach. Medial fracture patterns involve the posteromedial plateau, which requires a posteromedial approach. Occasionally through same skin incision, a separate anteromedial interval in front of or between the pes-anserine tendons can be used to reduce and fix through posteromedial approach.

Postero-lateral Approach:

If there is posterolateral comminution which is difficult to stabilize from an anterolateral approach, this approach is used. If the posterior plateau is comminuted far on the lateral side, it cannot be reached through the posteromedial approach. In such cases, a posterolateral approach between the lateral gastrocnemius and the biceps femoris with mobilization of the peroneal nerve will provide access to the posterolateral tibial plateau. This approach can be combined with a posteromedial approach which was described by Carlson.^{76,77}

Extensile Anterior Approaches:

Extensile approaches from the anterior portion of the knee have been used for complex tibial plateau fractures.⁷⁸⁻⁸⁰ Exposure will be similar to that of total knee arthroplasty

They provide simultaneous access for medial and lateral tibial plateau. Exposures where the extensor mechanism is elevated with a tibial tubercle fracture provide an intra-articular exposure to reduce fractures which are impossible.

Unfortunately, these exposures, when combined with dual plating, lead to excessive soft tissue stripping and devascularization of damaged fracture fragments, and when they resulted in infection and/or wound breakdown, disastrous results followed. For these reasons, alternate techniques should be chosen if at all possible. Current opinion and data indicate that dual plates can be reasonably safely applied to the fractured proximal tibia but that dual approaches are safer than extensile approaches.

Posterior Approaches:

Posterior approaches done in the prone position through the popliteal fossa have been used to treat posterior fracture patterns but have fallen out of favor because of the need to mobilize the neurovascular bundle. **Bhattacharyya⁸¹ et al**, treated group of patients with an

approach that divides the medial head of the gastrocnemius tendon, and Bendayan⁸² described an approach where the medial gastrocnemius was split. Most recently, Fakler et al.⁸³ used the Lobenhoffer approach for posteromedial fractures. This approach uses the same interval as the previously described posteromedial approach between the pes anserine and the medial head of gastrocnemius. Carlson^{76,77} described combined posteromedial and posterolateral approaches to the back of the tibial plateau. These are efficacious for posterior shearing patterns where direct posterior plating is mechanically optimal. A posterior approach in the prone position has the advantage of reducing the fracture with the knee in extension with a more direct view of the fracture and screw paths. In addition to taking the medial head down makes for a more extensile exposure to visualize comminuted fractures. These advantages are offset by the more difficult positioning compared to the supine posteromedial approach and lack of readily available access to the lateral side for bicondylar fractures.

Combined Anterior and Posteromedial Approaches:

Fractures of both condyles are frequently treated with combined approaches using an anterolateral approach and posteromedial approach as described earlier.⁷⁵ Dual approaches provide access to complex bicondylar fractures but strip less soft tissue attachments than extensile anterior

approaches. The patient is positioned supine and the leg must externally rotate for the posteromedial portion of the approach. Anterolateral and posteromedial incisions are nearly at 180 degrees from each other, so short skin bridges are not an issue. Direct access to each injured condyle to reduce the fracture and to place implants is obtained, which minimizes the soft tissue dissection required.

SURGICAL PROCEDURE

Under spinal or general anaesthesia, Patient was placed in supine position. The operating limb was cleaned and draped. Limb should be free for reduction techniques during the surgery. Fracture reduction was done under C-arm guidance by closed methods using ligamentotaxis. Combined traction with Valgus or varus strain was done in flexion or extension of knee as per the need of the individual case depending upon the reduction. Compression bony clamp was used in cases to bring the fracture fragments together. After confirming the reduction under C-arm guidance fixation of the fracture was done with locking plate.

Methodology

MATERIALS AND METHODS

Tibial plateau fractures treated by minimally invasive plate osteosynthesis using locking compression plate from January 2010 to January 2015 were taken into the study.

Inclusion criteria:

Age group: 18 years to 60 years

All tibial condyle fracture treated by minimally invasive plate osteosynthesis.

Exclusion criteria:

- 1) Skeletally immature patients,
- 2) Neurovascular injuries,
- 3) Concomitant lowerlimb fractures like patella, femur, ankle and pelvic fractures.
- 4) Open fractures

Methodology:

This was both retrospective as well as a prospective study. For the retrospective study in-patients and out-patient records of the study population were collected from the medical records department and OT register.

Age, gender of the patients, mode of injury, side of involvement, associated injuries and medical comorbidities were documented. The Neurovascular status of the affected leg, compartment syndrome and any blisters or open wounds was noted.

All Tibial condyles fractures were graded preoperatively using Schatzker classification. Patients were followed up postoperatively after a minimum period of six months after surgery. All the patients who had completed the inclusion criteria were called for assessment of functional outcome of knee using Rasmussen score and knee society score.

Operative technique

Under spinal or general anaesthesia, Patient was placed in supine position. The operating limb was cleaned and draped. Limb should be free for reduction techniques during the surgery. Fracture reduction was done under C-arm guidance by closed methods using ligamentotaxis. Combined traction with Valgus or varus strain was done in flexion or extension of knee as per the need of the individual case depending upon the reduction. Compression bony clamp was used in cases to bring the fracture fragments together. After confirming the reduction under C-arm guidance fixation of the fracture was done with locking plate through MIPPO.

Minimal skin incision for type VI schatzker fracture



In case of schatzker type III fracture depression was elevated with bent Steinmann pin introduced from the opposite condyle with or without bone grafting. After proper wound wash, wound was closed in layers with drain insitu. Postoperatively standard anteroposterior and lateral radiographs were taken.

CARM PICTURE SHOWING ELEVATION OF DEPRESSION



CLINICAL PICTURE SHOWING ELEVATION OF THE DEPRESSED FRACTURE



PRE OP XRAY



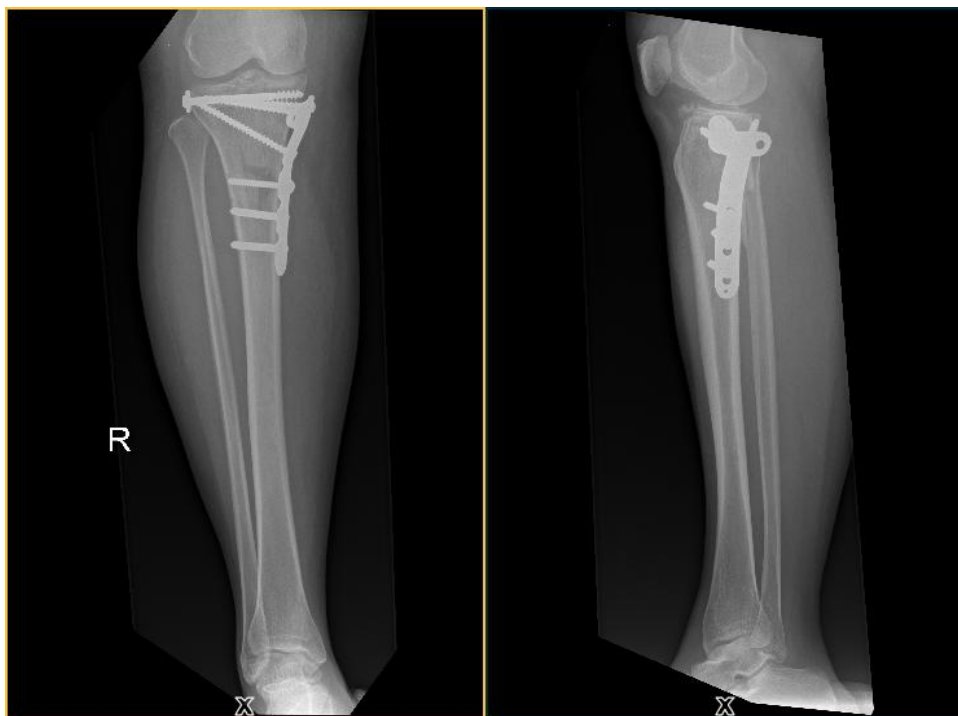
C-ARM picture shows large posteromedial fracture fragment.



**Intra-operative C-arm picture shows reduction of the fracture
fragment with locking plate.**



POST OP XRAY



MINIMAL INCISION- HEALED SURGICAL SCAR



Functional outcome of the knee was assessed after a minimum period of six months after surgery using Rasmuseen score and knee society score.

Knee Society Score²⁷

Clinician's name

Patient's name

Part 1 - Knee Score

Pain

<input type="radio"/> None
<input type="radio"/> Mild / Occasional
<input type="radio"/> Mild (Stairs only)
<input type="radio"/> Mild (Walking and Stairs)
<input type="radio"/> Moderate – Occasional
<input type="radio"/> Moderate – Continual
<input type="radio"/> Severe

Flexion Contracture (if present)

<input type="radio"/> 5°-10°
<input type="radio"/> 10°-15°
<input checked="" type="radio"/> 16°-20°
<input type="radio"/> >20°

Extension lag

<input type="radio"/> <10°
<input type="radio"/> 10-20°
<input type="radio"/> >20°

Total Range of Flexion						Alignment (Varus & Valgus)					
<input type="radio"/> 0-5	<input type="radio"/> 6-10	<input type="radio"/> 11-15	<input type="radio"/> 16-20	<input type="radio"/> 21-25		<input type="radio"/> 0	<input type="radio"/> 1	<input type="radio"/> 2	<input type="radio"/> 3	<input type="radio"/> 4	
<input type="radio"/> 26-30	<input type="radio"/> 31-35	<input type="radio"/> 36-40	<input type="radio"/> 41-45	<input type="radio"/> 46-50		<input type="radio"/> 5-10					
<input type="radio"/> 51-55	<input type="radio"/> 56-60	<input type="radio"/> 61-65	<input type="radio"/> 66-70	<input type="radio"/> 71-75		<input type="radio"/> 11	<input type="radio"/> 12	<input type="radio"/> 13	<input type="radio"/> 14	<input type="radio"/> 15	
<input type="radio"/> 76-80	<input type="radio"/> 81-85	<input type="radio"/> 86-90	<input type="radio"/> 91-95	<input type="radio"/> 96-100		<input type="radio"/> Over 15°					
<input type="radio"/> 101-105	<input type="radio"/> 106-110	<input type="radio"/> 111-115	<input type="radio"/> 116-120	<input type="radio"/> 121-125							

Stability (Maximum movement in any position)

Antero-posterior

<input type="radio"/> <5mm
<input type="radio"/> 5-10mm
<input type="radio"/> 10+mm

Mediolateral

<input type="radio"/> <5°
<input type="radio"/> 6-9°
<input type="radio"/> 10-14°
<input type="radio"/> 15°

Knee Society Score - Function

Clinician's name

Patient's name

Part 2 – Function

Walking

☐ Unlimited

☐ >10 blocks

☐ 5-10 blocks

☐ <5 blocks

☐ Housebound

☐ Unable

Stairs

☐ Normal Up and down

☐ Normal Up down with rail

☐ Up and down with rail

☐ Up with rail, down unable

☐ Unable

Walking aids used

☐ None used

☐ Use of Cane/Walking stick deduct

☐ Two Canes/sticks

☐ Crutches or frame

Function Score (Knee Society Score) is

Knee Society clinical rating system has a separate knee score with 50 points for pain, 25 points for range of motion, and 25 points for stability. Points are deducted for flexion contracture, extension lag, and malalignment. A separate patient function score assigns 50 points for stair climbing and 50 points for walking distance, with deductions for walking aids.

RASMUSEEN SCORE

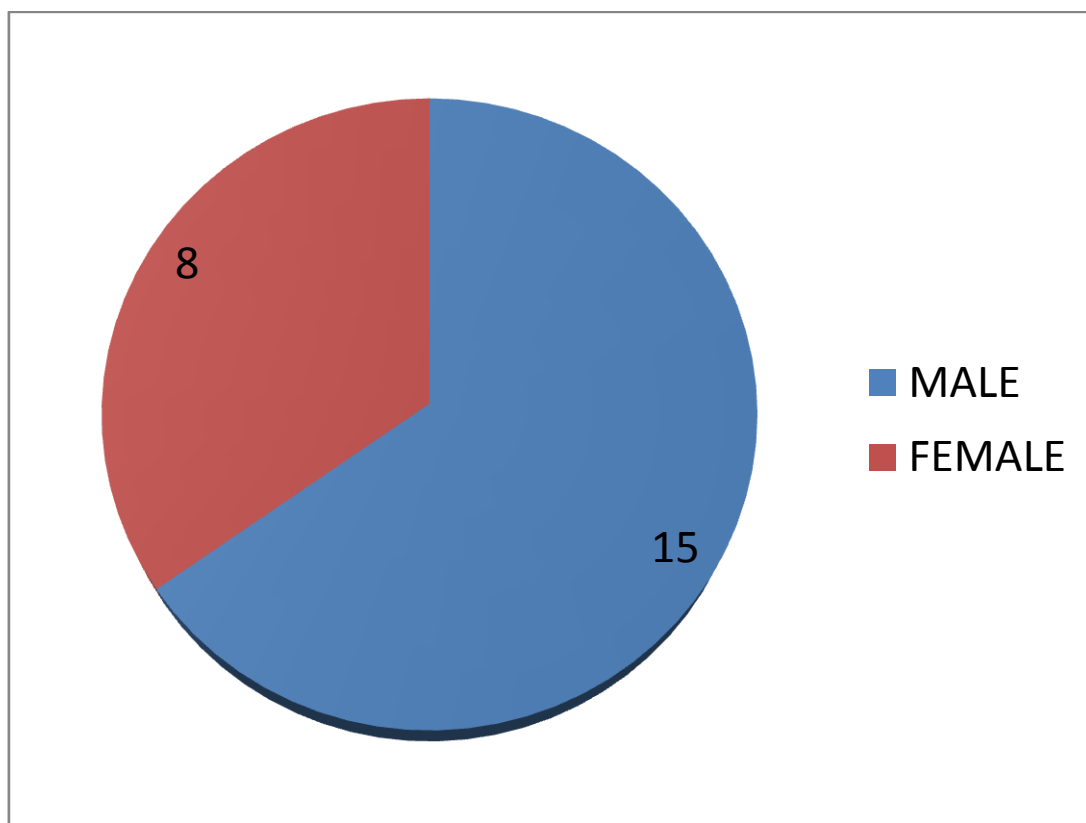
	Points	Acceptable		Unacceptable	
		Excellent	Good	Fair	Poor
A. Subjective complaints					
a. Pain					
No pain	6				
Occasional ache, bad weather pain	5				
Stabbing pain in certain positions	4	5	4	2	0
Afternoon pain, intense, constant pain around the knee after activity	2				
Night pain at rest	0				
b. Walking capacity					
Normal walking capacity (in relation to age)	6				
Walking outdoors at least one hour	4	6	4	2	1
Short walks outdoors > 15 minutes	2				
Walking indoors only	1				
Wheel-chair/bedridden	0				
B. Clinical signs					
a. Extension					
Normal	6				
Lack of extension (0 to 10 degrees)	4	6	4	2	2
Lack of extension > 10 degrees	2				
b. Total range of motion					
At least 140	6				
At least 120	5				
At least 90	4	5	4	2	1
At least 60	2				
At least 30	1				
0	0				
c. Stability					
Normal stability in extension and 20 degrees of flexion	6				
Abnormal instability 20 degrees of flexion	5	5	4	2	2
Instability in extension < 10 degrees	4				
Instability in extension > 10 degrees	2				
Sum (minimum)		27	20	10	6

Results

RESULTS

In our study Twenty three patients were assessed between January 2010 to January 2015 of which fifteen cases were male and eight of them were female.

TOTAL NUMBER OF CASES



Mean age of the male patient was 51.6 and female was 42.8 years.

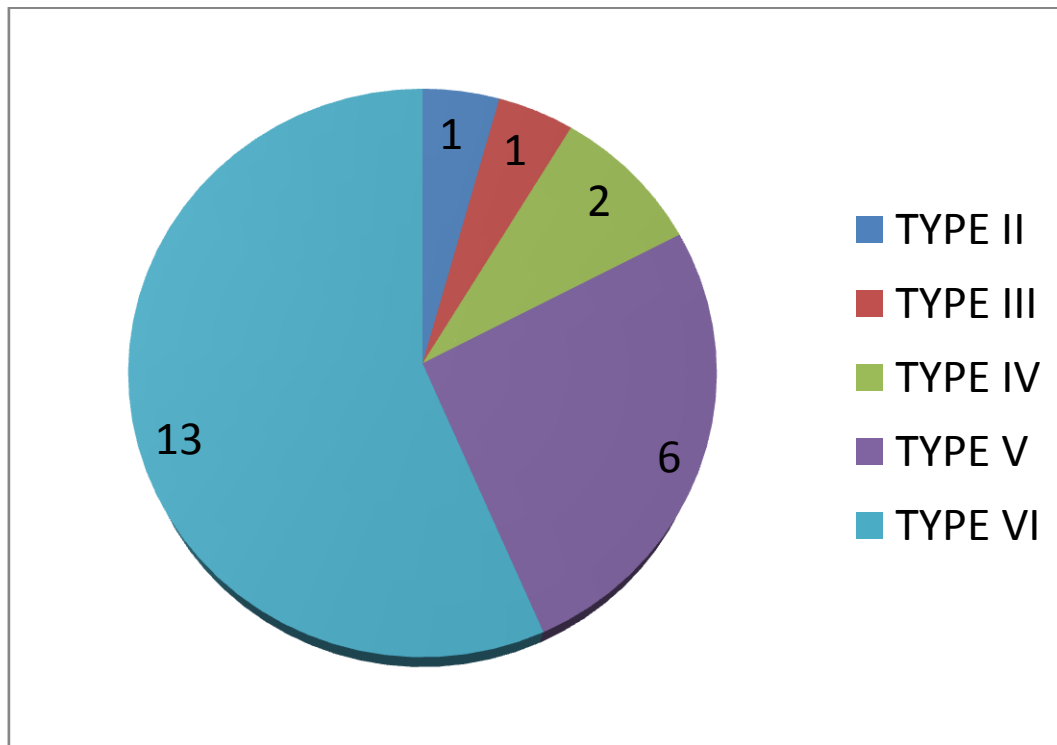
Average age group of type II, III, IV, V and VI Schatzker fractures was 56, 54, 43, 48.3 and 50.7 respectively.

AVERAGE AGE GROUP IN ALL 6 TYPES

SL.NO	TYPE	MEAN AGE GROUP
1	1	-
2	2	56
3	3	54
4	4	43
5	5	48.3
6	6	50.7

In our study, 13 patients belonged to type VI, 6 patients belonged to type V, 2 patients belonged to type IV, 1 patient belonged to type III and type II respectively.

TOTAL NUMBER OF PATIENTS



Thirteen patients had right tibial plateau fractures and remaining ten patients had left tibial plateau fractures. Only fractures which were treated with MIPPO technique were taken for the study. RTA was the mode of injury in all the cases. In our study type VI Schatzker fractures was the commonest type.

Functional assessment was assessed by Rasmussen score (subjective score) and knee society score (objective score). Average follow up period was 22.08 months.

MEAN FOLLOW UP

SL.NO	TYPE	AVERAGE FOLLOW UP (MONTHS)
1.	I	-
2.	II	17 (6-17)
3	III	18 (6-18)
4.	IV	32.5 (6-47)
5.	V	19.8 (6-27)
6.	VI	23.1 (6-53)

In type VI Schatzker there were thirteen patients of whom seven patients were treated by lateral plating and six patients were treated by medial plating.

TYPE	LATERAL PLATING	MEDIAL PLATING
1	-	-
2	1	-
3	1	-
4	-	2
5	2	4
6	7	6

Mean rasmuseen score of type VI fractures was found to be 25.6, average knee society score was found to be 93.2 and mean range of knee flexion was found to be 118.8 degrees. All fractures united by 12 weeks. All the patients were started on partial weight bearing from 8 weeks and full weight bearing by 12 weeks.

**AVERAGE SCORES BY KNEE SOCIETY AND RASMUSSEN
SCORE**

SL.NO	TYPE	KNEE SOCIETY SCORE	RASMUSEEN SCORE
1	1	-	-
2	2	98	27
3	3	96	29
4	4	94	26.4
5	5	81.3	22.8
6	6	93.2	25.6

Six patients belonged to type V Schatzker group. Mean follow up was 19.8 months (6-27). Lateral plating was done for 2 patients and medial plating was done for 4 patients. Average rasmuseen score was 22.8, mean knee society score was 81.3 and average range of knee flexion was found to be 118.3 degrees. Only one patient had flexion contracture of 10 degrees. All fractures united by 12 weeks. All the patients were started on partial weight bearing at 8 weeks and full weight bearing was started at 12th week. Postoperatively there were no wound infections.

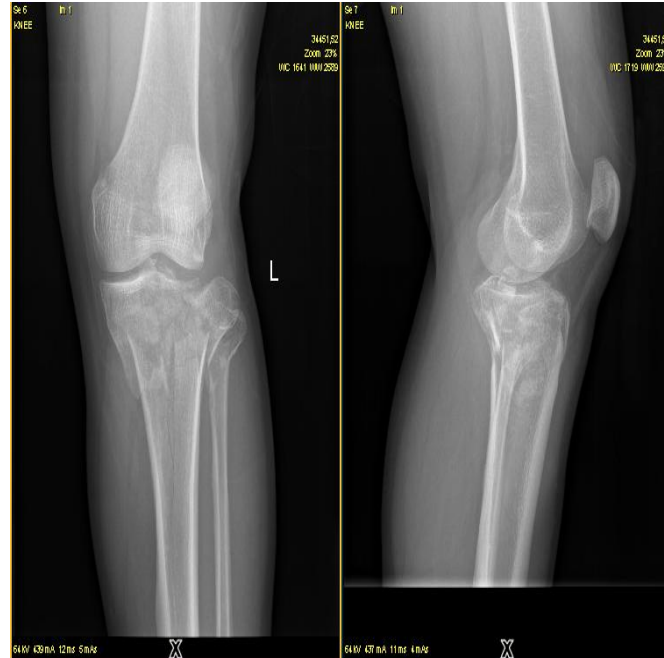
In type IV Schatzker fractures there were two patients. Mean follow up was found to be 32.5 months (6-47). All patients were treated by medial plating. Average range of flexion was found to be 122.5 degrees. Mean rasmuseen score was found to be 26.5. Mean knee society score was found to be 94. There was no wound infection and weight bearing was started at 12th week.

In our study only one patient belonged to type III Schatzker fracture. Follow up was done at 18 months (6-18). He was treated by lateral plating and had rasmuseen score of 29. Range of flexion was found to be 120 degrees. Knee society score was found to be 96. No complications were noted.

In type II Schatzker there was only one case which met the criteria. Lateral plating was done. Follow up was done at 17 months (6-17). Rasmuseen score was found to be 27, knee society score was 98 and range of knee motion was 125 degrees. No complications were noted. No bone grafts used in our study.

CASE 1:

PREOP XRAY



IMMEDIATE POSTOP XRAY

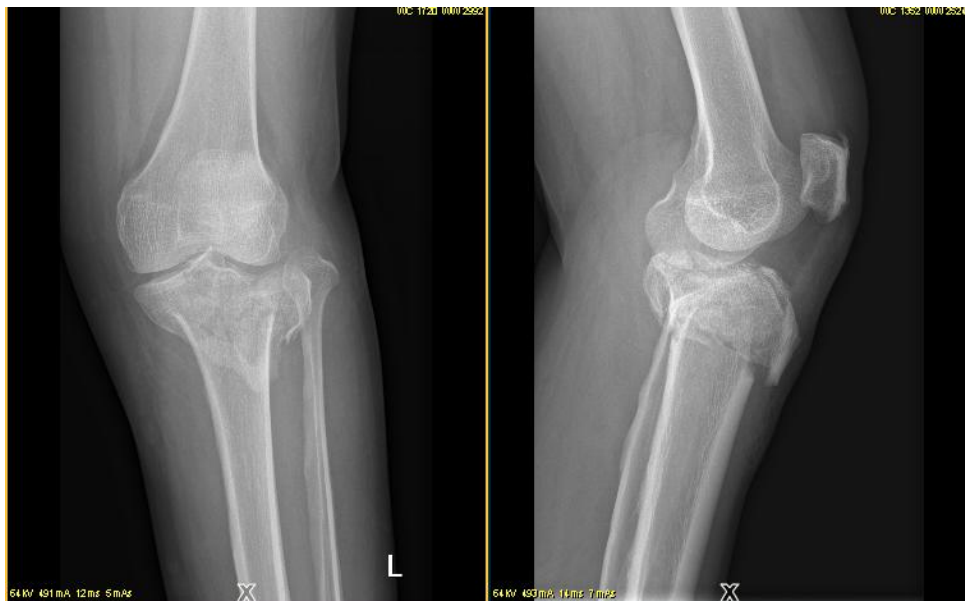


CLINICAL PICTURE



CASE 2:

PREOP XRAY



IMMEDIATE POSTOP



POSTOP 6 MONTHS



POSTOP CLINICAL PICTURE AFTER 6 MONTHS



Discussion

DISCUSSION

Intraarticular tibial plateau fractures are complex fractures accounting for about 1.2% of all fractures.⁸⁷ They affect knee function and stability which results in considerable morbidity. These fractures are caused by high velocity injuries and often associated with severe comminution and soft-tissue damage. The goals of treatment are to restore joint congruity, limb alignment and early mobilisation of joint.⁸⁴⁻⁸⁶ Stable internal plate fixation without damaging the soft-tissue envelope is very difficult to achieve,⁸⁸ only fair results are seen in 20% to 50% in these fractures.⁸⁹

Open reduction and internal fixation (ORIF) with plates and screws enables direct fracture visualisation, reduction, and fixation, but there is high risk of soft tissue injury, stiffness and deep infection.¹⁰² The hybrid external fixator avoids soft tissue problems, but risks malalignment, pin tract infections and poor patient compliance.^{103,34}

The concept of preserving the blood supply and atraumatic surgical technique led to the development of biological fixation techniques. Using this technique, soft tissue damage is reduced and shows higher union rate.⁹⁰⁻⁹³

The development of locking implants has allowed the use of minimally invasive technique for unilateral plating³⁷⁻³⁹ with improvement in handling the soft tissue.⁴¹⁻⁴³

Laterally placed locking plates provide better stability in the presence of complex proximal 1/3rd tibia fracture with metaphyseal comminution and serves as an alternative to medial plate or external fixator for additional support of the medial column when a non-locking plate is used for bicondylar fractures.^{94,95} This plate allows fixation through single incision which avoids wound dehiscence, infection and prolonged immobilisation associated with extensile approaches.⁹⁶⁻⁹⁹

MIPPO enables indirect fracture reduction and percutaneous sub muscular implant placement.¹⁰⁰ Favourable outcome is not due to MIPPO but due to less extensive dissection of soft-tissue envelope and devitalisation of fracture fragments.

The aim of our study was to evaluate the functional outcome of tibial condyle fractures treated by minimally invasive percutaneous plate osteosynthesis.

There is no universal scoring system for assessing the functional outcome for these fractures. Literature shows multiple scoring system like Rasmussen, knee society score and oxford knee score.

In our study, we have evaluated the patients using Rasmussen score which is a subjective score and knee society score which is an objective score.

All these fractures were treated by a single plate either medial or lateral (11 lateral and 12 medial). In case of type V and type VI fractures, if needed the opposite condyle was fixed with percutaneous cancellous screws.

Mechanism of injury was road traffic accident for all these patients. The fractures were classified by Schatzker's classification. 13 patients belonged to type VI, 6 patients belonged to type V, 2 patients belonged to type IV, 1 patient belonged to type III and type II respectively. Even though, according to literature type II fractures were the most common, only one patient with type II fracture was included in our study as all other type II & type I fractures in the study period were fixed only by percutaneous screws hence excluded from the study. Type VI fracture with 13 patients (56.5%) were the most common in our study, next was type V (26.08) with 6 patients.

Average followup period was 22 months (6-53).

HASNAIN RAZA¹⁰¹ et al, in their study of assessing the functional outcome of tibial condyle fractures of 41 patients by minimally invasive

plate osteosynthesis by rasmuseen functional score found excellent results in 18 patients, good in 19 patients and 4 patients had unacceptable results. The mean rasmuseen score was found to be 25.3 and range of knee flexion was 118 degrees. In our study mean rasmuseen score was found to be 26.1 and average range of knee flexion was found to be 120.9 degrees. Of which ten patients had excellent and good results each. Only 3 patients had fair results. This is comparable to the study done by Hasnain Raza.

Mohammad Ali Tahririan, Seyyed Hamid Mousavitadi, and Mohsen Derakhshan¹³ in their clinical study comparing the functional outcomes of tibial plateau fractures treated with nonlocking and locking plate fixation by knee society score, found a score of 80.2 for locking plate and 72.5 for non locking plate. Average range of knee flexion was found to be 122.3 degrees for locking plate and 115.7 degrees for non locking plate. In our study, locking plate was used for all the cases. Average knee society score was found to be 92.5 and average knee flexion was found to be 120.9 degrees. So, functional outcome in our study was marginally better than the locking plate group in that study and significantly better than the non locking group. This shows the superiority of the locking plate in view of stable fixation and early range of motion when compared to non locking plate.

Chang-Wug Oh¹⁸ et al in their study on double plating of (twenty three) type V and type VI proximal tibial fractures using minimally invasive percutaneous osteosynthesis found Eighteen patients with excellent, three patients with good and two patients with fair results. Average rasmuseen score was found to be 26 and average knee range of motion was found to be 123 degrees.

In our study, nineteen patients belonged to type V and VI fractures. Average rasmuseen score of these type V and type VI fractures were found to be 24.2. Average range of flexion achieved by type V and type VI was found to be 118.5 degrees. Seven patients had excellent, ten patients with good and two patients had poor results.

In their study of ten patients **Kye-Youl Cho⁵ et al**, used a single midline longitudinal incision and dual plating for the treatment of type V and type VI schatzker fractures. Their mean knee society score for the study group was 85 and the mean range of motion was 125 degrees. They had only one case with delayed wound healing as postoperative complication. In our study, average knee society score was found to be 87.25. One patient had 10 degrees of valgus malalignment in type VI fracture and one patient had flexion contracture of 5-10 degrees. But the functional outcome was not significantly altered when compared with others.

Dual plate gives better biomechanical strength and rigid construct thereby better control of both columns thus avoiding late collapse. There were no major wound problems in any of these studies. Weight bearing was started only at 8-12 weeks which was similar to our study.

In our study, there was no late complications like loss of reduction and malalignment with unilateral plating for type V and type VI fractures. Functional outcome at midterm followup is similar to those two studies with dual plating. Since our study group is small we were not able to statistically conclude which procedure is better.

Choice of the procedure/implant should be based on the fracture pattern, bone quality and intraoperative reduction.

Conclusion

CONCLUSION

Treatment of intraarticular tibial plateau fractures is still unsolved.

Our results in minimally invasive percutaneous plate osteosynthesis (MIPPO) technique is in par with the literature.

There is no significant difference in the functional outcome between single plating in our study and dual plating of other studies at midterm followup. Choice of the procedure/implant should be based on the fracture pattern, bone quality and intraoperative fracture reduction.

LIMITATIONS

- 1) Study was very small comprising only twenty three patients. So it was impossible for any statistical correlation.
- 2) Our average followup period was 22 months. A long term followup of five to ten years could have been more significant.
- 3) Only functional assessment was studied, radiological outcome was not included.

CASE IMAGES

PREOP XRAY



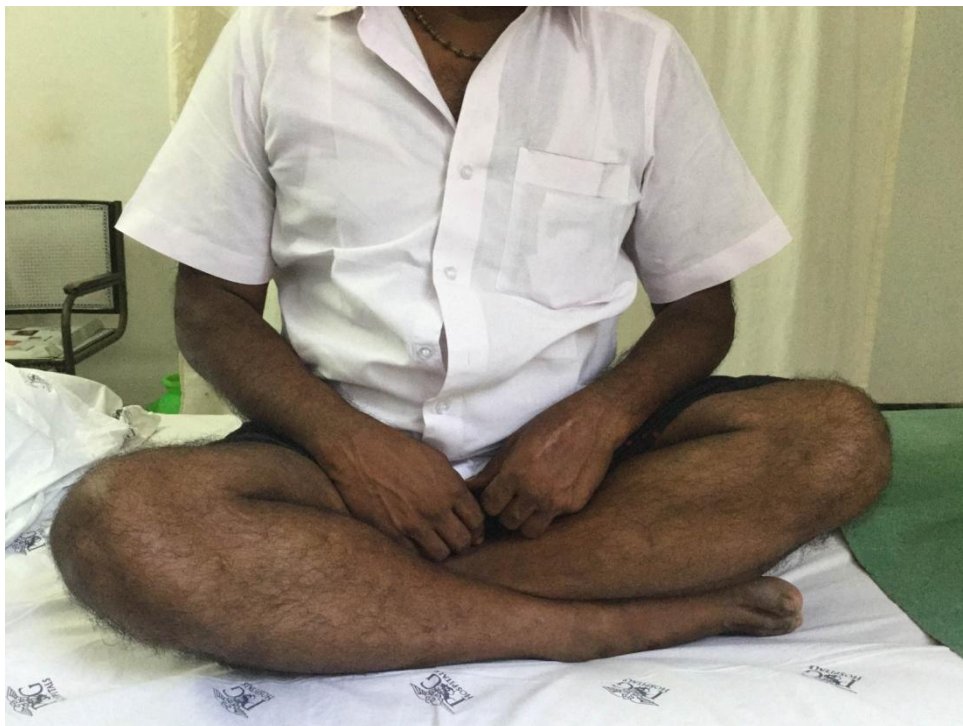
IMMEDIATE POSTOP XRAY



AFTER 6 MONTHS



CLINICAL PICTURE



CASE 2:

PREOP



IMMEDIATE POSTOP



6 MONTHS POSTOP



POSTOP CLINICAL PICTURE AFTER 6 MONTHS



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Master Chart

MASTER CHART FOR ALL THE PATIENTS

SL NO	NAME	AGE	TOTAL FLEXION	FLEXION CONTRACTURE	EXTENSION LAG	ALIGNMENT	STA AP	BILITY ML	KNEE SOCIETY SCORE	RASMUSEEN SCORE
1	BALASUBRAMANIAM	58	125	5-10	NIL	5-10	<5	<5	98	29
2	ARUMUGOM	52	100	NIL	NIL	5-10	<5	<5	86	23
3	MEENAKSHI	58	110	NIL	<10	5-10	<5	<5	95	24
4	RAMALAKSHMI	51	120	NIL	<10	5-10	<5	<5	96	29
5	PALANISAMY	38	125	NIL	NIL	5-10	<5	<5	89	24
6	SATHISH KUMAR	58	125	NIL	NIL	5-10	<5	<5	96	27
7	RAMAKRISHNAN	56	120	NIL	<10	5-10	10	<5	78	19
8	KAMALAM	54	120	NIL	NIL	5-10	<5	<5	96	29
9	RONICKAM	42	100	NIL	<10	5-10	<5	<5	94	25
10	SATHISH	52	125	NIL	NIL	5-10	<5	<5	98	29
11	KUMAR	42	125	NIL	NIL	5-10	<5	<5	76	23
12	SELVAM	48	120	NIL	<10	5-10	<5	<5	78	19
13	KRISHNAN	34	120	NIL	<10	5-10	<5	<5	72	24
14	SARAVANAN	32	125	NIL	<10	5-10	<5	<5	96	29
15	JOHNSON	48	120	NIL	NIL	5-10	<5	<5	97	27
16	NOORMOHAMME	58	120	NIL	<10	10	<5	<5	70	18
17	KANDHASAMY	54	120	NIL	NIL	5-10	<5	<5	92	24
18	SAROJA	50	125	NIL	NIL	5-10	<5	<5	94	27
19	VIJAYAKUMAR	56	125	NIL	NIL	5-10	<5	<5	98	27
20	MATHIYALAGAN	44	125	NIL	<10	5-10	<5	<5	96	29
21	PERUMALSAMY	53	110	NIL	NIL	5-10	<5	<5	93	26
22	GEETHARI	52	120	NIL	<10	5-10	<5	<5	97	24
23	VISWANATHAN	47	120	NIL	NIL	5-10	<5	<5	97	24